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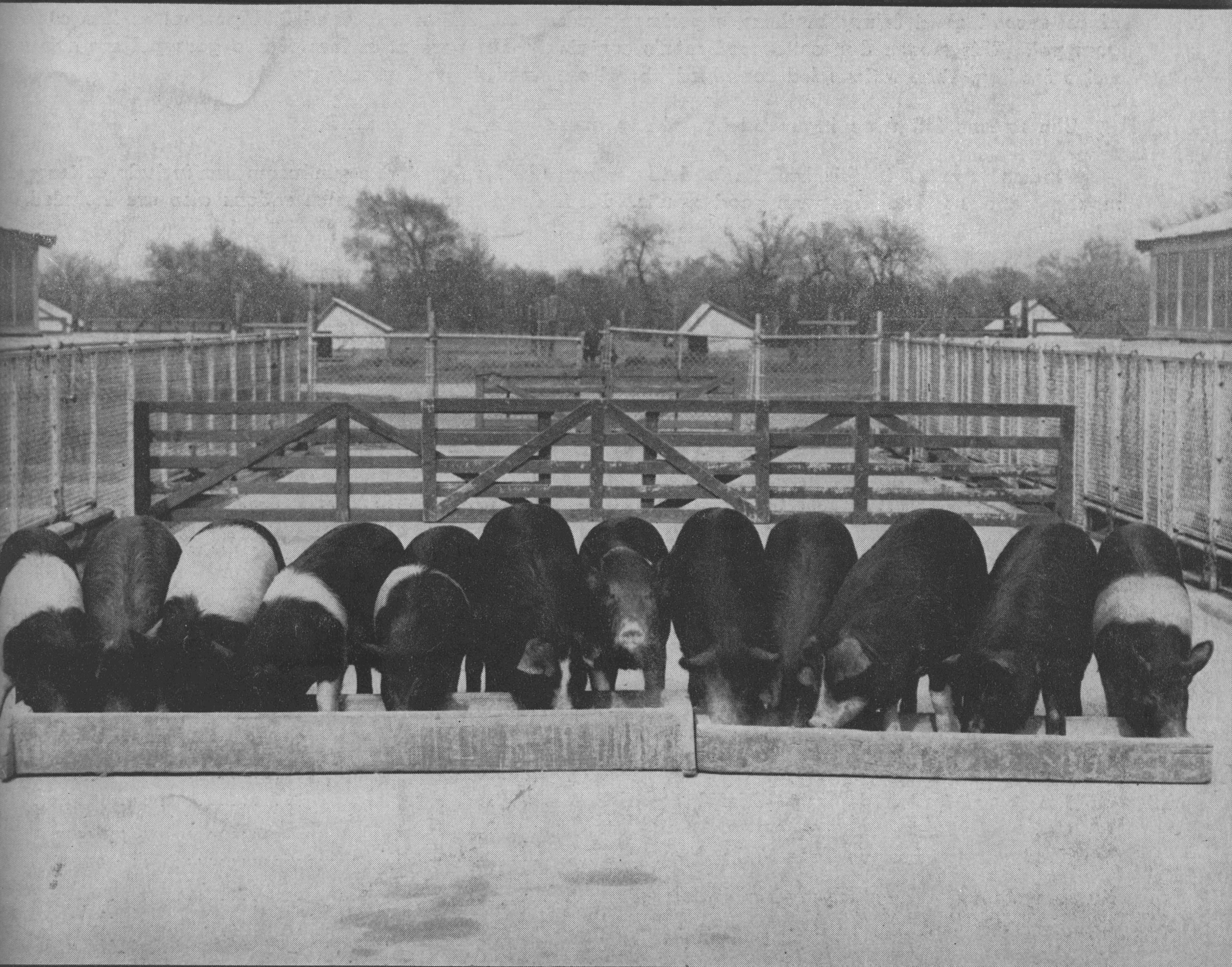
# Use of Cottonseed Meal in Swine Rations



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## SUMMARY

This bulletin contains the results of studies involving protein quality, lysine availability, amino acid content and gossypol tolerance as they relate to the use of cottonseed meal in swine rations. These studies also include the pathology of gossypol poisoning in pigs and the results of feeding trials with cottonseed meal made by different manufacturing processes.

Newer methods now available for processing and evaluating the protein quality and gossypol content have provided a way for making a cottonseed meal that can be used safely in complete feed mixtures or in protein supplements for swine.

When the complete ration for hogs contains not more than 0.01 percent of free gossypol, the pigs fed such rations will make good gains. No pigs have died nor have any pigs showed the slightest symptoms of cottonseed meal injury in these experiments when the ration contained 0.01 percent or less of free gossypol. This means that cottonseed meals containing 0.04 percent or less of free gossypol are safe for swine feeding. The rations fed contained liberal amounts of good quality protein.

The rations fed were improved by adding aureomycin and vitamin $B_{12}$.

Studies reported in this bulletin lead to the conclusions that swine producers can include cottonseed meal in rations fed to pigs with good results. Methods of formulating such rations also are included.

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# Use of Cottonseed Meal in Swine Rations

Fred Hale, Carl M. Lyman and Hilton A. Smith*

COTTONSEED MEAL, when used properly, is an excellent source of protein for use in swine rations. If the swine produced in the 13 Southern States alone were fed adequately balanced rations, they would require an amount of cottonseed meal equal to the production of about 2 million acres of cotton, figuring the average yield at two-thirds of a bale per acre.

Many tests on the use of cottonseed meal in swine rations have given poor results. These results were due largely to the quality of the meal or the way in which it was used. During recent years, information has been developed at the Texas Agricultural Experiment Station on the specifications of superior quality cottonseed meal and the factors which must be considered in its production, Lyman, Chang, and Couch (1953), Chang *et al.* (1955), Baliga and Lyman (1957) and Lyman and Baliga (1958). The program has been directed by Carl M. Lyman.

The protein supplement part of the well-balanced swine rations is the principal feedstuff that the hog farmer has to buy, and since cottonseed meal is rich in protein, and since it is a feed that is available in a wide area at all times, it is important that we should know more about its use in hog rations.

## EARLY OBSERVATIONS

Cottonseed meal can now be used in swine rations with excellent results. This statement was not true a few decades ago. In fact, early results from the feeding of cottonseed meal to hogs indicated that one might never be able to feed cottonseed meal in practical hog rations.

For example, Curtis and Carson (1892), at the Texas Agricultural Experiment Station, noted that pigs died in 6 to 8 weeks from the time of first feeding of cottonseed meal.

At the Kansas Station, Georgeson and Burtis (1895) found that when the ration contained 25 percent cottonseed meal, the pigs died in 3 to 8 weeks after they were started on the test ration.

Curtis (1895) at the Iowa Station found the meal toxic to pigs when the pigs had eaten 27 to 33 pounds per pig.

Dinwiddie (1903) at the Arkansas Station found that pigs receiving 0.6 to 0.8 pound daily of cottonseed meal died in 34 to 64 days after the test started.

Hale (1930) at the Texas Station found that rations containing a maximum of 9 percent cottonseed meal could be fed to fattening hogs as well as to breeding animals without producing undesirable effects. This report showing the condition under which cottonseed meal could be used safely and profitably was soon verified by other investigators and the way was open for the limited use of cottonseed meal in swine rations. Robinson (1934) found that cottonseed meal which was toxic at levels of 18 to 20 percent of the ration was not toxic when fed at a level of 10.5 percent of rations containing some tankage.

In these years, cottonseed meal meant hydraulic cottonseed meal since this was the major processing method at the time. Today there are a few straight solvent cottonseed meals with free gossypol content too high for the products to be used safely in swine rations at the 9 percent level. Such meals are excellent for cattle and sheep and should be fed only to ruminating animals.

At the Texas Station, Lyman, Holland and Hale (1944) studied the processing variables in the hydraulic method of cottonseed oil extraction and found that by the control of the variables, time, temperature and moisture content, meal of very low gossypol content could be produced in commercial mills. Several tons of meal containing 0.024 percent free gossypol were manufactured and fed to hogs at levels as high as 25 percent of the ration. No symptoms of gossypol toxicity were observed, but protein quality in this meal was not high and consequently the growth rate of the pigs was poor.

Cottonseed processing studies required better analytical methods. The first colorimetric method for the determination of free gossypol was developed by Lyman, Holland and Hale (1943). This development provided a new, accurate and fast method for the determination of free gossypol in cottonseed meal and hastened the way for producing a high quality cottonseed meal for swine and poultry.

The microbiological method for the determination of amino acids in natural feeds was developed at the Texas Station by Kuiken, Lyman and other co-workers (1943). This method has

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been used extensively in protein quality evaluation studies.

Harris (1947), with the use of isopropyl alcohol as the solvent, produced a solvent-extracted cottonseed meal at the Texas Station which gave good results when fed to pigs.

More recent studies on the use of cottonseed meal in swine rations are reported in this bulletin.

## FACTORS INVOLVED

Cottonseed meals manufactured under different processing conditions differ over a wide range with respect to their nutritional value as protein supplements for hogs. Because of this fact, feeding trials in which cottonseed meal is compared with other protein supplements are worthless unless information also is made available concerning the processing conditions or the chemical characteristics of the meals. Essentially the characteristics of a superior quality cottonseed meal for use in swine rations are: (1) it must be low in free-gossypol, 0.04 percent or less is recommended; and (2) it must contain high quality protein. High nitrogen solubility is a good indication of high protein quality in cottonseed meal. Seventy-five percent or higher nitrogen solubility in 0.02 N sodium hydroxide is recommended.

### Free Gossypol Tolerance

If cottonseed meal of high free gossypol content is used as the sole protein supplement for hogs for a long time, some of the animals are almost certain to die and the percentage loss is likely to be high. It is, therefore, important to know what is the maximum safe tolerance level for gossypol in swine rations. Table 1 gives the results of a test in which the level of free gossypol was varied from 0 to 0.028 percent. A 15.5 percent protein ration was used in this test. Free gossypol was supplied by mixing two cottonseed meals, one of very low and one of high free gossypol content. The composition of the rations for all groups except the control was: milo, 76.5 percent; mixed cottonseed meal, 9 percent; soybean oil meal, 9 percent; alfalfa leaf meal, 3 percent; limestone, 0.5 percent; salt, 0.5 percent; and aurofac (containing aureomycin and vitamin $B_{12}$), 0.5 percent. The ration for the control group contained 18 percent soybean meal and no cottonseed meal.

The pigs used in these tests were purebred Durocs bred and raised by the Texas Agricultural Experiment Station. They represented the kind and weight often purchased as feeder pigs for commercial feeding. Both barrows and gilts were used. The pigs were kept and fed in individual pens with concrete floors and with an outside concrete pen adjacent to the pen inside the feeding shed. Both the inside and outside pens were 4 feet by 8 feet in size. Each pen inside the barn contained an individual self-feeder and each outside pen contained an individual water trough. The pens were cleaned and washed daily.

The results (Table 1) indicate that, under the conditions of this experiment, 0.01 percent free gossypol in the ration is a safe level. All animals which received 0.01 percent free gossypol or less showed no gossypol toxicity symptoms and the gain was as good or almost as good as in the control group where the ration contained soybean meal as the sole protein supplement. There were no death losses with 0.015 percent free gossypol in the diet, but two pigs showed gossypol toxicity symptoms as indicated by severe thumping or labored breathing. This labored breathing was due to partial congestion of the lungs with fluid. Deaths occurred in all groups receiving more than 0.015 percent free gossypol.

Informal reports made at the third conference on Processing as Related to Nutritive Value of Cottonseed Meal, which was held at the Southern Regional Research Laboratory in New Orleans in 1953, indicated a lack of agreement among investigators concerning the highest level of free gossypol which should be considered safe for swine. The discovery that gossypol tolerance

TABLE 1. EFFECT OF FREE GOSSYPOL LEVEL IN THE DIET ON GROWING-FATTENING PIGS, 70-DAY TEST

| Item | Crude protein level of diets 15.5% | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Percent gossypol in diet | | | | | | | | |
| | None | .0013 | .0025 | .007 | .010 | .015 | .019 | .022 | .028 |
| Group number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Number of animals[1] | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Initial weight, pounds | 57.6 | 57.6 | 57.8 | 57.6 | 57.6 | 57.7 | 57.6 | 57.7 | 57.7 |
| Final weight, pounds | 192.4 | 192.4 | 181.3 | 187.3 | 188.8 | 184.8 | 178.7[2] | 185.8[2] | 161.6[2] |
| Average daily gain, pounds | 1.92 | 1.92 | 1.76 | 1.85 | 1.87 | 1.81 | 1.70[2] | 1.83[2] | 1.52[2] |
| Feed per 100 pounds gain | 367.4 | 377.5 | 374.0 | 348.2 | 364.2 | 361.7 | 364.5 | 351.4 | 373.8 |
| Number of deaths | None | None | None | None | None | None | 1 | 2 | 2 |
| Number of animals which lived, but showed gossypol toxicity symptoms | None | None | None | None | None | 2 | 2 | None | 4 |

[1]Pigs fed in individual pens.
[2]For animals remaining at close of test.

TABLE 2. COMPOSITION OF RATIONS

| Item | 15% protein rations | | | | 30% protein rations | | | |
|---|---|---|---|---|---|---|---|---|
| Ration number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Cottonseed meal, pounds | 0 | 1.6 | 3.2 | 4.8 | 0 | 1.6 | 3.2 | 4.8 |
| Soybean meal, pounds | 13.0 | 11.8 | 10.8 | 8.0 | 52.4 | 51.4 | 50.0 | 47.4 |
| Milo, (grain sorghum), pounds | 81.0 | 80.6 | 80.0 | 81.2 | 41.6 | 41.0 | 40.8 | 41.8 |
| Alfalfa leaf meal, pounds | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| Limestone, pounds | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Salt, pound | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Aurofac, pound | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |

levels vary with the amount and quality of the protein in the diet offers a sound basis for interpreting this apparent discrepancy.

Table 2 gives the ration used in a gossypol-tolerance test with two levels of protein. Gossypol was supplied in the form of hexane-extracted cottonseed meats prepared in a commercial mill with a minimum of heat. The meal contained 0.64 percent free gossypol and 38.25 percent protein. The protein content of the soybean meal was 47.94 percent.

The results of the test are shown in Table 3. With a 15 percent crude protein diet, 0.01 percent free gossypol did not produce symptoms of gossypol toxicity, but gave slightly lower growth rate than the control group receiving no gossypol. Levels of free gossypol above 0.01 percent resulted in toxicity symptoms and the death of some animals in each group. These results are in agreement with those obtained in the first experiment (Table 1).

In sharp contrast, no animal receiving the 30 percent protein ration showed any symptoms of gossypol toxicity. When these animals were slaughtered at the termination of the experiment, no internal symptoms could be found by a qualified veterinarian who examined them.

Table 4 shows the amount of gossypol consumed by individual animals during the test period. Animals which died on the 15 percent protein ration had consumed up to 39.6 grams of gossypol. Every animal in the groups fed 30 percent protein rations and either 0.02 or 0.03 percent gossypol in the ration consumed more gossypol than did any of those which died on the 15 percent protein ration, yet none died and none showed any gossypol toxicity symptoms.

The relationship between gossypol tolerance level and the amount and quality of the protein in the ration has been substantiated by reports from three different laboratories. In addition to the investigation with swine at the Texas Agricultural Experiment Station, Cabell and Earle (1956) conducted experiments with rats and Earle and Stevenson (1957) used swine.

## Protein Quality and Lysine Availability

The nutritional value of a protein depends on the kind and relative amounts of amino acids which it contains and on the digestibility of the protein. Table 5 shows the amino acid composition of cottonseed meal and the grains, corn and milo, which are generally fed with this protein supplement. The amino acids which are likely to be deficient in farm rations for swine are tryptophan, methionine and lysine. Cottonseed meal is a good source of tryptophan and a fair source of methionine, but is deficient in lysine. Lysine is thus the limiting amino acid in a cottonseed meal-corn or cottonseed meal-milo type of ration.

Perhaps of more importance is the fact that a portion of the lysine in cottonseed meal cannot be digested, absorbed and utilized by the animals. Lysine availability is, therefore, a major factor in determining the quality of protein in cottonseed meal. Perhaps no other major protein

TABLE 3. EFFECT OF PROTEIN LEVEL IN THE RATION ON GOSSYPOL TOLERANCE IN GROWING-FATTENING PIGS, 84-DAY TEST

| Item | Standard protein level, 15% C.P. | | | | High protein level, 30% C.P. | | | |
|---|---|---|---|---|---|---|---|---|
| | % gossypol in diet | | | | % gossypol in diet | | | |
| | 0 | .01 | .02 | .03 | 0 | .01 | .02 | .03 |
| Ration number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Number of animals[1] | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Initial weight, pounds | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 |
| Final weight, pounds | 204 | 190 | 170[2] | 135[3] | 188 | 191 | 186 | 177 |
| Average daily gain, pounds | 1.74 | 1.57 | 1.31 | 1.16 | 1.55 | 1.58 | 1.52 | 1.42 |
| Feed per 100 pounds gain, pounds | 366 | 376 | 424 | 461 | 387 | 379 | 381 | 384 |
| Number of deaths | None | None | 2 | 4 | None | None | None | None |
| Number of animals which lived, but showed gossypol toxicity symptoms | None | None | 3 | 2 | None | None | None | None |

[1]Pigs fed in individual pens.
[2]6 remaining animals.
[3]4 remaining animals.

TABLE 4. GOSSYPOL CONSUMED BY INDIVIDUAL PIGS

| 15% protein ration | | | | 30% protein ration | | | |
|---|---|---|---|---|---|---|---|
| .02% gossypol | | .03% gossypol | | .02% gossypol | | .03% gossypol | |
| Pig number | Total gossypol consumed, grams | Pig number | Total gossypol consumed, grams | Pig number | Total gossypol consumed, grams | Pig number | Total gossypol consumed, grams |
| 93 | 51.8 | 23[1] | 29.6 | 30 | 51.1 | 80 | 65.4 |
| 3[2] | 35.7 | 51[3] | | 50 | 45.4 | 40 | 62.9 |
| 104[1] | 39.6 | 20[2] | 26.4 | 21 | 45.2 | 79 | 64.4 |
| 39[2] | 31.1 | 130[1] | 35.6 | 81 | 40.9 | 70 | 57.1 |
| 106 | 53.6 | 75[2] | 44.5 | 125 | 44.9 | 74 | 62.0 |
| 151 | 51.6 | 55 | 54.5 | 46 | 43.2 | 87 | 71.4 |
| 44[2] | 28.9 | 68 | 52.3 | 123 | 42.7 | 133 | 66.2 |
| 110[1] | 24.9 | 36[1] | 24.0 | 126 | 41.8 | 77 | 50.9 |
| Average | 39.7 | | 38.1 | | 44.4 | | 62.5 |

[1]Animals which died with symptoms of gossypol poisoning.
[2]Animals which showed gossypol toxicity symptoms but did not die.
[3]Removed from lot 3 weeks after test started because of leg injury and general unthriftiness.

concentrate varies as much in protein quality as does cottonseed meal. Such variations are largely the result of variations in manufacturing conditions.

Variations in protein quality in cottonseed meal can be measured in small animal feeding trials with rats. Table 6 shows the wide variations found in different samples. Wide variations in lysine availability in a collection of cottonseed meal are shown in Table 7. There is as much variation in protein quality among different samples of cottonseed meal made by any one processing method as there is between different manufacturing procedures. The exact conditions used in any process are of primary importance.

A modification of the Cannon (1944) rat protein repletion test described by Cabell and Earle (1954) was used for the protein quality evaluations. The procedure for the determination of lysine availability was described by Baliga and Lyman (1957).

Lyman, Change and Couch (1953) studied the chemical characteristics of cottonseed meal as these are related to nutritional value. A relationship was found between protein quality and nitrogen solubility in 0.02 N sodium hydroxide and protein quality. This test has been very useful as a mill control in the production of superior quality cottonseed meal.

Several commercial milling processes are now followed for the production of low gossypol, high protein quality cottonseed meal for use in swine and poultry rations.

## Fiber

Growing and fattening pigs do not digest crude fiber as well as do cattle or sheep. The rate of gain is depressed when the fiber content of the ration for fattening pigs is 7.5 percent or more (Bohstedt *et al.*, 1933). The amount of feed required for a given gain, however, increases regularly with rations containing more than about 4.5 percent crude fiber (Lathrop *et al.*, 1938).

Cottonseed meal, as now manufactured, contains a considerable amount of hulls. The production of cottonseed meal with less hulls would yield a product with higher protein content and lower crude fiber. Such a meal would be more efficient as a protein supplement for swine.

Soybean meal with a 50 percent crude protein guarantee and with less than 3.5 percent crude fiber is now being sold for use in poultry and swine rations.

TABLE 5. ESSENTIAL AMINO ACID CONTENT OF COTTONSEED MEAL, CORN AND MILO

| Amino acid | Cottonseed meal | | Corn | | Milo | |
|---|---|---|---|---|---|---|
| | In the sample, % | In crude protein, % | In the sample, % | In crude protein, % | In the sample, % | In crude protein, % |
| Arginine | 4.38 | 11.02 | 0.37 | 4.60 | 0.45 | 4.39 |
| Histidine | 1.07 | 2.70 | 0.22 | 2.73 | 0.22 | 2.15 |
| Isoleucine | 1.59 | 4.01 | 0.33 | 4.10 | 0.46 | 4.49 |
| Leucine | 2.46 | 6.20 | 0.95 | 11.80 | 1.22 | 11.90 |
| Lysine | 1.67 | 4.20 | 0.27 | 3.35 | 0.24 | 2.34 |
| Methionine | 0.59 | 1.49 | 0.18 | 2.24 | 0.18 | 1.75 |
| Phenylalanine | 2.09 | 5.25 | 0.42 | 5.22 | 0.50 | 4.88 |
| Threonine | 1.38 | 3.47 | 0.31 | 3.85 | 0.41 | 4.00 |
| Tryptophan | 0.63 | 1.59 | 0.087 | 1.17 | 0.140 | 1.36 |
| Valine | 1.98 | 4.98 | 0.43 | 5.34 | 0.58 | 5.66 |
| Protein content | 39.61 | | 8.05 | | 10.25 | |

TABLE 6. PROTEIN QUALITY IN DIFFERENT SAMPLES OF COTTONSEED MEAL AS DETERMINED BY RAT PROTEIN REPLETION TESTS

| Meal number | Type of processing | Rat protein repletion value, grams gain in weight in 10 days |
|---|---|---|
| 1 | Solvent extraction | 39.3 |
| 2 | Prepress solvent | 38.7 |
| 3 | Solvent, extraction | 36.1 |
| 4 | Hydraulic press | 24.4 |
| 5 | Slow speed screw press | 22.6 |
| 6 | Prepress solvent | 20.9 |
| 7 | High speed screw press | 18.2 |

## PATHOLOGY OF GOSSYPOL POISONING[1]

The pigs that died came from lots receiving free gossypol in an amount between 0.02 to 0.03 percent of the total ration. The 0.01 percent or less level of free gossypol did not result in the death of any pigs.

The animals that died had been on the gossypol ration 38 to 79 days, with the exception of 2 which survived until the 93rd day. Even the highest level of gossypol used was not necessarily lethal. Many pigs showed only retarded growth when marketed at the usual age of 6 to 8 months.

In the seriously poisoned animals, signs of illness were typically apparent 2 to 6 days, or, exceptionally, as long as 1 month. The outstanding symptom was always dyspnea, with violently labored respirations which stockmen call thumping. Progressive weakness and emaciation were accompanied by a good appetite almost until death.

Widespread congestion and edema were salient post-mortem lesions. The lungs and liver were markedly congested in all cases; the kidneys, spleen and lymph nodes, in many.

Large amounts of fluid often were encountered in the pleural, pericardial and peritoneal cavities. Edema of the lungs, present in all cases, was commonly so extensive that a frothy fluid was visible in the trachea. In accordance with accepted principles, the edema was considered to have been dependent on passive congestion and venous stasis. The latter conditions were attributed to a progressively failing heart on the basis of both symptoms and lesions, Figure 1. The occurrence of gross pathologic lesions resulting with rations containing 0.02 to 0.03 percent free gossypol are listed in Table 8.

All livers were congested grossly, with at least a suspicion of intralobular necrosis or other degenerative changes. The livers generally were reddish with the lobular architecture possibly more prominent than normal. In the pig, this is normally conspicuous because of the distinct interlobular septa. Microscopic examination revealed a startling change in all the livers (Figure 2). While in 5 pigs the destruction was only partial, the remaining 13 had almost no viable parenchymal cells. In these, only a narrow rim of hepatic cells remained at the extreme periphery of each lobule. The remainder of the lobular space was filled with blood, although a scattered reticulum of Kupffer cells appeared to be intact.

While extensive areas of the skeletal muscles frequently were pale or almost white, it was difficult to demonstrate microscopically any change beyond an abnormal variation in the size

[1]Further information may be found in paper by Smith, 1957.

TABLE 7. VARIATION IN LYSINE AVAILABILITY IN DIFFERENT SAMPLES OF COTTONSEED MEAL AS DETERMINED BY RAT FEEDING TESTS AND NITROGEN SOLUBILITY

| Meal designation | Type of processing | Lysine availability | Nitrogen solubility in 0.02 N NaOH |
|---|---|---|---|
| A | Experimental solvent extraction | 80.7 | 83.1 |
| B | Screw press | 82.6 | 87.7 |
| C | Prepress solvent | 76.9 | 75.9 |
| D | Commercial meal not identified | 68.1 | 64.5 |
| E | Screw press | 55.3 | 53.7 |
| F | Screw press | 53.2 | 53.7 |
| G | Screw press | 50.7 | 50.9 |

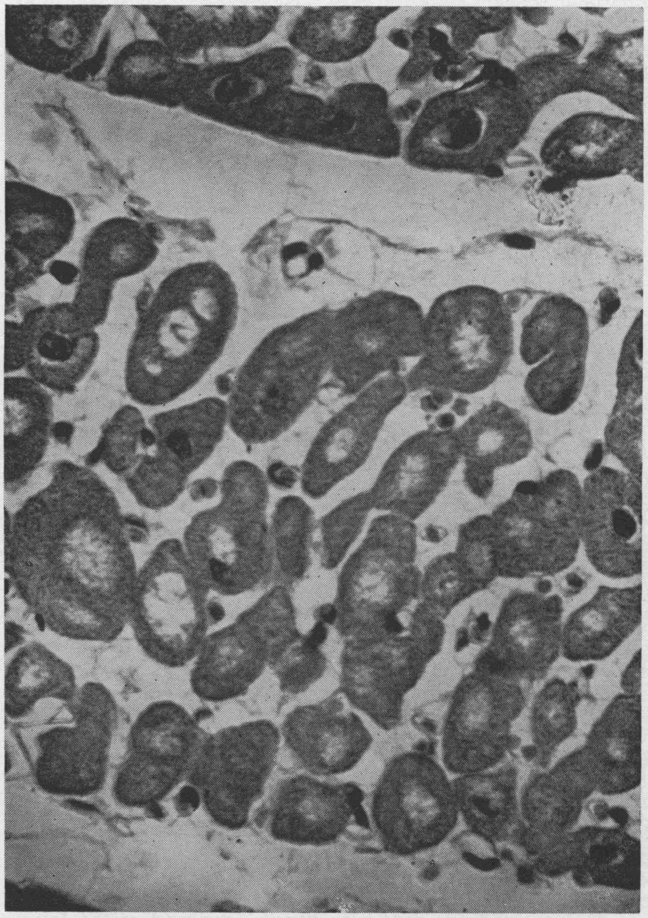

Figure 1. Degenerative changes in heart muscle.

TABLE 8. GROSS PATHOLOGIC LESIONS OBSERVED IN 18 PIGS FED RATIONS CONTAINING 0.02 TO 0.03 PERCENT FREE GOSSYPOL

| Animal number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subcutaneous edema | + | | | | + | | + | | | + | | | + | | | | + | + |
| Hydrothorax | + | + | | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| Congestion and edema of lungs | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| Hydropericardium | + | + | | | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| Dilatation of heart | + | + | + | + | + | + | + | + | + | + | | + | + | | + | | | + |
| Hypertrophy of heart | | | | | + | + | | | + | | | + | + | | | | | |
| Hydroperitoneum | + | | | + | + | + | + | + | + | + | | + | | | | + | + | + |
| Edema of gallbladder | | + | + | | + | + | + | + | + | | | | + | | | | | |
| Edema of lymph nodes | + | + | + | + | + | + | + | + | + | + | + | + | + | | + | + | | + |
| Congestion (and necrosis) of liver | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| Congestion of kidney | + | | + | + | | + | + | | + | + | + | + | + | | + | | | + |
| "White muscles" | + | + | | | + | + | + | + | + | + | + | | | | | | | + |
| Icterus | | | | | | | | | | | | | | + | | | + | + |

of certain fibers some being atrophied, others hypertrophied (Figure 3).

The lesions portrayed are nearly identical to the lesions described by West (1940) in dogs fed poisonous amounts of cottonseed meal, except that gastroenteritis was more prominent in the dogs and petechial and ecchymotic hemorrhages were numerous. The centrilobular destruction of liver cells was less pronounced in the dogs.

In contemplating the almost unprecedented changes found in the liver, the question arises

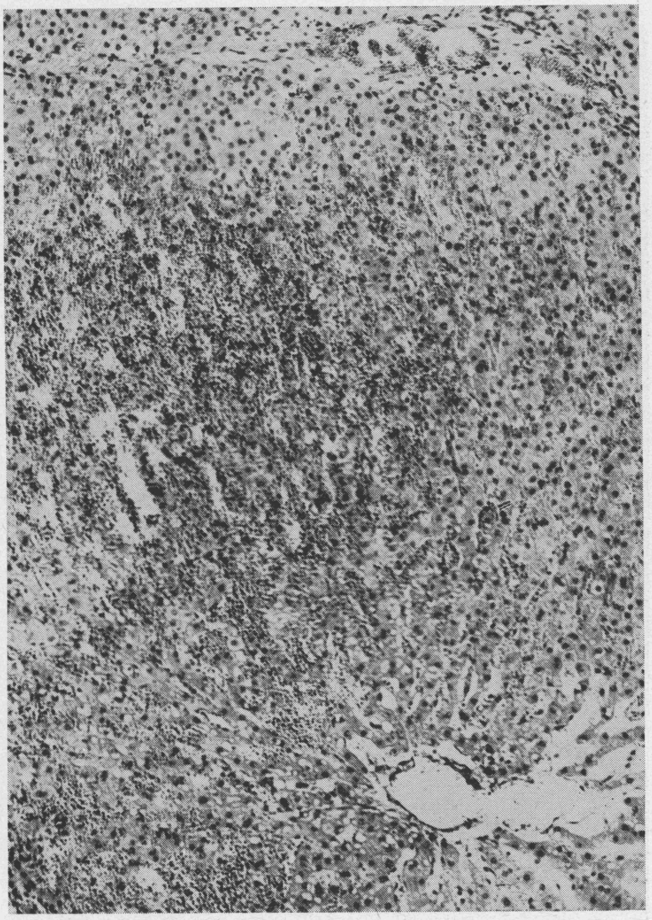

Figure 2. Early lesion in liver. One part of the lobule has undergone necrosis and is being replaced with blood.

whether this degree of hepatic injury results from the anoxia consequent upon congestion and stasis of blood, or whether a direct hepatotoxic action must be attributed to the gossypol. Also advocated has been the theory that increased blood pressure in the intralobular capillaries destroys the hepatic cells by pressure necrosis. Without attempting an unequivocal answer to this problem, certain similar and possibly related disorders of dietetic nature are the most intriguing, as well as the most perplexing.

Hove and Seibold (1955) fed a diet low in protein (soybean meal), markedly deficient in vitamin E and containing cod-liver oil, of which highly unsaturated fatty acids are characterisic constituents. After 1 to 4 months on this diet, the animals usually died and, at necropsy, showed a "hemorrhagic necrosis" of the liver similar in most respects to the hepatic condition ascribed to gossypol. Cirrhosis developed in pigs that lived for 6 months. The authors considered the livers to be comparable with those produced by Obel (1953), who described a porcine disease known as hepatosis diaetetica which occurs naturally in Sweden and Northern Europe and which was susceptible of experimental reproduction by the combined deleterious effects of (1) inadequate dietary protein (brewer's yeast, which is deficient in the sulfur-containing amino acids), (2) deficiency of vitamin E and (3) presence in the diet of considerable amounts (6 percent) of cod-liver oil with its highly unsaturated fatty acids. The similarities between the lesions arising from excessive gossypol and those described for natural or experimental cases of hepatosis diaetetica are seen in the necrotic and blood-filled hepatic lobules and in the concomitant presence of extensive edema in practically identical situations and in the presence of retrograde changes in the skeletal and cardiac musculature which, while called by different names, appear microscopically to have at least the degenerative features in common. However, certain notable differences between the cases of gossypol poisoning and those which Obel (1953) and Hove and Seibold (1955) found to result from dietetic imbalances are readily apparent both in clinical and post-mortem aspects.

TABLE 9. CHEMICAL ANALYSES OF COTTONSEED MEALS USED IN FEEDING TRIALS 1, 2 AND 3

| Meal description | Protein content, % | Free gossypol, % |
|---|---|---|
| Screw press, S-51 | 40.38 | 0.020 |
| Screw press, S-59 | 37.44 | 0.027 |
| Screw press, S-514 | 40.00 | 0.027 |
| Isopropanol extracted | 46.12 | 0.013 |
| Hydraulic | 42.25 | 0.04 |
| Degossypolized | 39.80 | 0.04[1] |

[1]Approximate value. A special analytical method is required for accurate determination on this type of meal. The method became available after this work was completed.

## TRIALS WITH DIFFERENT MEALS

Six different cottonseed meals, all with a free gossypol content not exceeding 0.04 percent, were fed in three tests as the sole protein supplement to growing-fattening pigs without symptoms of gossypol toxicity. These tests included commercial screw press and hydraulic meals, a special process degossypolized meal and an experimental meal made by solvent extraction with isopropyl alcohol. Results of these tests give further evidence that low gossypol cottonseed meal does not produce unfavorable physiological effects on hogs.

Table 9 shows the chemical composition of the meals used in these tests. The rations used in feeding trial 1 are given in Table 10 and the results are shown in Table 11. One of the conclusions drawn from this test is that aureomycin plus vitamin $B_{12}$ significantly increased the growth rate of the groups fed screw-press and isopropanol-extracted cottonseed meals. A second finding of importance is that a screw-press meal plus aureomycin and vitamin $B_{12}$ gave growth rates and feed efficiency equal to those obtained with meat scraps.

### Growth—Trial 1

The group of pigs fed the control ration containing meat scraps (lot 7) made highly significantly greater average daily gains ($P=.01$) than the combined groups of pigs on rations containing cottonseed meals without aurofac.

There was no significant difference in average daily gains between the pigs receiving the control ration (lot 7) and the pigs receiving cottonseed meal S-514 plus aurofac (lot 4) or the group of pigs receiving the isopropanol-extracted cottonseed meal plus aurofac (lot 6).

The pigs receiving cottonseed meal S-514 plus aurofac (lot 4) made highly significantly greater average daily gains ($P=.01$) than the group of pigs receiving the same meal without the aurofac (lot 3). The same highly significant difference was shown for the pigs receiving isopropanol-extracted meal plus aurofac (lot 6) over the group of pigs receiving the isopropanol-extracted cottonseed meal without the aurofac (lot 5).

No significant difference was found between combined groups of pigs receiving screw-press cottonseed meal without aurofac (lots 1, 2 and 3) and the pigs receiving the isopropanol-extracted cottonseed meal (lot 5) without the aurofac.

The pigs receiving the isopropanol-extracted cottonseed meal plus aurofac (lot 6) made significantly greater average daily gain ($P=.05$) than the group receiving the screw-press cottonseed meal plus aurofac (lot 4).

### Feed per 100 Pounds Gain—Trial 1

There was no significant difference in feed required per 100 pounds of gain between the control pigs receiving meat scraps in the ration (lot 7) and the combined groups of pigs receiving cottonseed meal rations without aurofac (lots 1, 2, 3 and 5). Neither was there a significant difference in the feed required per 100 pounds of gain between the control group receiving meat scraps in the ration (lot 7) and the group receiving cottonseed meal S-514 plus aurofac (lot 4). However, the pigs in lot 6 receiving isopropanol-extracted cottonseed meal used significantly less feed per 100 pounds of gain ($P=.05$)

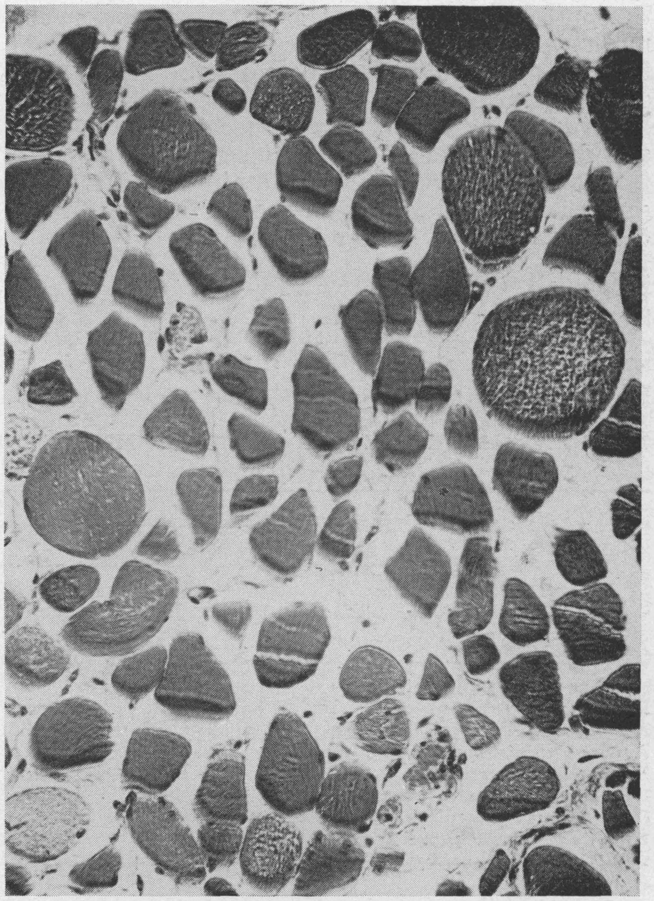

Figure 3. Degenerative changes in skeletal muscle.

TABLE 10. COMPOSITION OF RATIONS USED IN FEEDING TRIAL 1

| Group number | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Ground milo, pounds | 79 | 77 | 79 | 79 | 81 | 81 | 84 |
| Screw press C.S.M.[1] S-51, pounds | 16 | | | | | | |
| Screw press C.S.M. S-59, pounds | | 18 | | | | | |
| Screw press C.S.M. S-514, pounds | | | 16 | 16 | | | |
| Isopropanol extracted C.S.M., pounds | | | | | 14 | 14 | |
| Meat scraps, pounds | | | | | | | 12.5 |
| Alfalfa leaf meal, pounds | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Limestone, pounds | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Salt, pound | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Aurofac[2], pound | 0 | 0 | 0 | 0.5 | 0 | 0.5 | 0 |

[1]C.S.M.=cottonseed meal.
[2]Contained 1.8 grams aureomycin and 1.8 milligrams vitamin $B_{12}$ per pound.

than did the pigs in lot 7 (the control group) receiving meat scraps.

The pigs in group 6 receiving cottonseed meal S-514 plus aurofac used significantly less feed per 100 pounds of gain (P=.05) than the pigs in lot 5 receiving the same meal without the aurofac.

The pigs receiving isopropanol-extracted cottonseed meal plus aurofac (lot 6) used highly significantly less feed per 100 pounds of gain (P=.01) than the pigs receiving the same meal without aurofac (lot 5).

Table 12 shows the rations used in feeding trial 2 and the results of this test are given in Table 13. Two different screw-press cottonseed meals, S-51 and S-59, gave growth rates equal to those obtained with soybean meal. The sample of hydraulic meal was not as good as these two screw-press meals, but gave better growth rate and feed efficiency than meat scraps. The addition of aureomycin plus vitamin $B_{12}$ increased growth rate and improved feed efficiency in the test with hydraulic cottonseed meal.

## Growth—Trial 2

No significant difference was found in the average daily gain of the combined groups of pigs receiving the expeller-processed cottonseed meals, S-51 and S-59, plus aurofac (lots 1 and 2) and the pigs receiving soybean meal plus the aurofac (lot 5).

The pigs receiving hydraulic-processed cottonseed meal plus aurofac (lot 4) made significantly greater average daily gains (P=.05) than the pigs receiving the hydraulic meal without the aurofac (lot 3).

The combined groups of pigs receiving expeller-processed cottonseed meals plus aurofac (lots 1 and 2) made highly significantly greater average daily gains (P=.01) than did the pigs receiving meat scraps plus the aurofac (lot 6).

The group of pigs receiving soybean oil meal plus aurofac (lot 5) also made highly significantly greater gains (P=.01) than did the pigs receiving meat scraps plus the aurofac (lot 6).

## Feed per 100 Pounds Gain—Trial 2

There was no significant difference in the average feed required per 100 pounds of gain between the combined groups of pigs receiving expeller cottonseed meal, S-51 and S-59, plus aurofac (lots 1 and 2) and the pigs in lot 4 receiving hydraulic-processed meal plus aurofac. Neither was there any significant difference in the feed required per 100 pounds of gain between the combined groups of pigs receiving

TABLE 11. PERFORMANCE DATA OF PIGS FED MEAT SCRAPS AND COTTONSEED MEALS MADE BY DIFFERENT PROCESSES, FEEDING TRIAL 1[1]

| Item | Lot 1 | Lot 2 | Lot 3 | Lot 4 | Lot 5 | Lot 6 | Lot 7 |
|---|---|---|---|---|---|---|---|
| | Screw press C.S.M. S-51 | Screw press C.S.M. S-59 | Screw press C.S.M. S-514 | Screw press C.S.M. S-514 + aurofac[2] | Iso-propanol extracted C.S.M. | Iso-propanol extracted C.S.M. + aurofac[2] | Meat scraps |
| Number of pigs per lot | 6[3] | 6[3] | 6[3] | 7 | 7 | 7 | 7 |
| Length of test, days | 84 | 84 | 84 | 84 | 84 | 84 | 84 |
| Average final weight, pounds | 195.6 | 191.8 | 186.8 | 214.8 | 191.4 | 221.1 | 216.6 |
| Average initial weight, pounds | 68.6 | 68.6 | 68.3 | 66.7 | 66.7 | 66.7 | 66.7 |
| Total gain, pounds | 127.0 | 123.2 | 118.5 | 148.1 | 124.7 | 154.4 | 149.9 |
| Average daily gain, pounds | 1.51 | 1.46 | 1.41 | 1.76 | 1.48 | 1.84 | 1.78 |
| Feed per 100 pounds gain, pounds | 411.0 | 394.3 | 406.6 | 375.0 | 406.0 | 365.4 | 393.7 |
| Total feed eaten, pounds | 3132 | 2914 | 2891 | 3889 | 3545 | 3950 | 4130 |

[1]Complete ration mixed and fed in self-feeder.
[2]Contained 1.8 grams aureomycin and 1.8 milligrams vitamin $B_{12}$ per pound.
[3]One pig removed from test because of unthriftiness.

TABLE 12. COMPOSITION OF RATIONS USED IN FEEDING TRIAL 2

| Group number | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Ground milo, pounds | 79 | 77 | 80 | 80 | 81 | 84 |
| Screw press C.S.M. S-51, pounds | 16 | | | | | |
| Screw press C.S.M. S-59, pounds | | 18 | | | | |
| Hydraulic C.S.M., pounds | | | 15 | 15 | | |
| Soybean oil meal, pounds | | | | | 14 | |
| Meat scraps, pounds | | | | | | 11 |
| Alfalfa leaf meal, pounds | 3 | 3 | 3 | 3 | 3 | 3 |
| Salt, pound | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Limestone, flour, pounds | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Aurofac[1], pound | 0.5 | 0.5 | | 0.5 | 0.5 | 0.5 |

[1]Contained 1.8 grams aureomycin and 1.8 milligrams vitamin $B_{12}$ per pound.

expeller cottonseed meal, S-51 and S-59, plus aurofac (lots 1 and 2) and the group of pigs receiving soybean oil meal plus the aurofac.

No significant difference was found in the feed required per 100 pounds of gain between the pigs receiving hydraulic-processed cottonseed meal (lot 3) and the pigs receiving hydraulic-processed cottonseed meal plus aurofac (lot 4).

The combined groups of pigs receiving expeller cottonseed meal, S-51 and S-59, plus aurofac (lots 1 and 2) used highly significantly less feed per 100 pounds of gain ($P=.01$) than did the group of pigs receiving meat scraps plus the aurofac (lot 6).

Pigs receiving hydraulic-processed cottonseed meal plus aurofac (lot 4) used highly significantly less feed per 100 pounds of gain ($P=.01$) than did pigs receiving meat scraps plus aurofac (lot 6).

The group of pigs receiving soybean oil meal plus aurofac (lot 5) used highly significantly less feed per 100 pounds of gain ($P=.01$) than did the pigs receiving meat scraps plus the aurofac (lot 6).

There was no significant difference in the feed required per 100 pounds of gain between pigs receiving soybean oil meal plus aurofac (lot 5) and the pigs receiving hydraulic-processed cottonseed meal plus the aurofac (lot 4).

Results of a comparative test with soybean oil meal and a sample of degossypolized cottonseed meal supplied by the Buckeye Cotton Oil Company are given in Table 14. In this test, degossypolized cottonseed meal gave growth rates and feed efficiency almost as good as those obtained with soybean oil meal. The degossypolized cottonseed meal used in this test was manufactured by the use of an aromatic amine to combine with and inactivate free gossypol.

Unfortunately, the three feeding trials reported were carried out before the nitrogen solubility test using 0.02 N sodium hydroxide was developed and, consequently, information on the solubility of the protein in these samples is not available.

The free gossypol content of the ration containing degossypolized cottonseed meal (lot 2) was 0.0096 percent. The difference in gain and in feed required per 100 pounds of gain between the two lots was not significant. Although the pigs fed the ration containing 24 percent degossypolized meal made good gains, a ration with a part of the cottonseed meal replaced with soybean meal would have a better distribution of essential amino acids.

## AUREOMYCIN PLUS VITAMIN $B_{12}$ WITH MEALS

The addition of aurofac containing aureomycin plus vitamin $B_{12}$ to rations in which cottonseed meals (hydraulic, screw-press or isopropanol-extracted) were used as the protein concentrate consistently resulted in more rapid

TABLE 13. PERFORMANCE DATA OF PIGS FED SCREW PRESS COTTONSEED MEAL, HYDRAULIC COTTONSEED MEAL, SOYBEAN OIL MEAL AND MEAT SCRAPS, FEEDING TRIAL 2

| Group number | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Protein supplement | Screw press C.S.M. S-51 | Screw press C.S.M. S-59 | Hydraulic C.S.M. | Hydraulic C.S.M. | Soybean meal | Meat scraps |
| Aurofac[1] | Added | Added | | Added | Added | Added |
| Number of pigs | 7 | 7 | 6[2] | 6[2] | 7 | 6[2] |
| Average initial weight, pounds | 502 | 501 | 445 | 443 | 501 | 432 |
| Average final weight, pounds | 1448 | 1490 | 968 | 1150 | 1457 | 978 |
| Average total gains, pounds | 946 | 989 | 523 | 707 | 956 | 546 |
| Average daily gains, pounds | 1.75 | 1.83 | 1.13 | 1.53 | 1.77 | 1.18 |
| Average total feed consumption, pounds | 517 | 548 | 367 | 464 | 513 | 413 |
| Feed per 100 pounds gain, pounds | 384 | 388 | 427 | 394 | 375 | 454 |

[1]Lederle's $B_{12}$ concentrate with aureomycin contains 1.8 grams of aureomycin and 1.8 milligram of vitamin $B_{12}$ per pound.
[2]One pig was removed from lots 3, 4 and 6 because of sickness followed by general unthriftiness.

TABLE 14. DEGOSSYPOLIZED COTTONSEED MEAL AND SOYBEAN MEAL AS PROTEIN SUPPLEMENTS FOR GROWING-FATTENING PIGS, FEEDING TRIAL 3

| Performance data | Soybean meal | Degossypolized cottonseed meal |
|---|---|---|
| Lot number | I | II |
| Number of pigs per lot[1] | 8 | 8 |
| Length of test, days | 70 | 70 |
| Average final weight, pounds | 201 | 193 |
| Average initial weight, pounds | 69 | 69 |
| Total gain, pounds | 132 | 124 |
| Average daily gain, pounds | 1.88 | 1.75 |
| Total feed eaten, pounds | 3788 | 3640 |
| Feed per 100 pounds gain, pounds | 358.7 | 370 |
| Composition of rations | % | % |
| Milo | 74.5 | 70.0 |
| Soybean meal | 20 | 0 |
| Cottonseed meal | 0 | 24 |
| Alfalfa leaf meal | 3 | 3 |
| Ground limestone | 1.5 | 1.5 |
| Salt | 0.5 | 0.5 |
| Aurofac[2] | 0.5 | 0.5 |

[1]Pigs were fed in individual pens.
[2]Contained 1.8 grams aureomycin and 1.8 milligram vitamin $B_{12}$ per pound.

gains. This conclusion was verified by further tests not included in these tables.

## COTTONSEED AND SOYBEAN MEALS AS PROTEIN SUPPLEMENTS

Table 15 shows the results obtained in a test in which a protein supplement containing soybean meal was compared with a supplement in which 50 percent of the soybean meal was replaced with a low gossypol, high-protein quality cottonseed meal.

TABLE 15. USE OF LOW GOSSYPOL-HIGH PROTEIN QUALITY COTTONSEED MEAL[1] AND SOYBEAN MEAL IN SUPPLEMENTS FOR GROWING-FATTENING PIGS[2]

| Group number | 1 | 2 |
|---|---|---|
| | Composition of protein supplements, pounds | |
| Cottonseed meal | 37 | 0 |
| Soybean meal | 37 | 74 |
| Alfalfa leaf meal | 19 | 19 |
| Limestone | 4 | 4 |
| Salt | 1 | 1 |
| Aurofac[3] | 2 | 2 |
| | Growth rate and feed efficiency[4] | |
| Number of pigs | 8 | 8 |
| Average initial weight, pounds | 64.7 | 64.8 |
| Average final weight, pounds | 219.6 | 214.1 |
| Average daily gain, pounds | 2.01 | 1.94 |
| Feed required per 100 pounds gain: | | |
| Milo, pounds | 341.3 | 322.2 |
| Protein supplement, pounds | 43.5 | 50.4 |
| Total feed, pounds | 384.8 | 372.6 |

[1]The cottonseed meal used in this test contained 0.033% free gossypol and had a nitrogen solubility of 74.1%.
[2]Protein supplement and milo were fed free choice in self-feeders.
[3]Aurofac (1.8 grams aureomycin, 1.8 milligrams $B_{12}$ per pound).
[4]Differences in gain and feed utilization were not statistically significant at the 5% level. Pigs in each group fed in individual lots.

The pigs were fed in individual pens for 77 days. The straight soybean meal supplement was slightly more palatable than the cottonseed-soybean meal mixture since the pigs getting the soybean meal supplement ate 7 pounds more supplement per pig during the test.

The pigs getting the mixed supplement gained 0.07 pound more per pig per day, but the difference was not significant.

There was no significant difference in feed required per 100 pounds of gain for the two groups, although the pigs getting the soybean meal supplement required 0.12 pound less feed per pound of gain.

The pigs getting the cottonseed-soybean meal mixture ate 2.2 percent less supplement per 100 pounds of gain, which indicates that when these feeds are fed free-choice in self feeders, the chances are that the pigs will overeat a straight soybean meal supplement before they would a cottonseed-soybean meal mixture. This would tend to make the cottonseed-soybean meal mixture more economical to feed.

## RECOMMENDATIONS

Two methods of feeding are used in swine production. In the first method, the feeds used are mixed completely for self-feeding or the mixture can be fed by hand, usually twice per day. In the second method, a protein supplement mixture is formulated to be fed in one compartment along with corn or milo in a second compartment of a self-feeder, free-choice. A third compartment of the self-feeder is used frequently for a mineral mixture.

### Mixed Rations

Table 16 shows the percentage of crude protein needed in complete or mixed rations for different classes and weights of hogs.

In formulating rations for complete mixtures, one can use enough high quality cottonseed meal to furnish 25 percent of the crude protein for mixtures containing 15 to 16 percent crude protein.

High quality cottonseed meal can furnish 30 percent of the crude protein for mixtures containing 12 to 14 percent total crude protein where the cottonseed meal contains 0.04 percent or less of free gossypol.

Thirty-seven to 40 pounds of cottonseed meal can be used in a 100-pound protein supplement mixture. This protein supplement mixture can then be mixed with ground grain to formulate the complete mixtures containing the percentage of crude protein recommended in Table 16.

TABLE 16. RECOMMENDED PROTEIN CONTENT OF SWINE RATIONS

| Class of hogs | Growing and fattening hogs | | | Breeding stock | | | |
|---|---|---|---|---|---|---|---|
| | | | | Sows | | Boars | |
| | Weaned to 100 pounds | 100 to 200 pounds | 200 to 240 pounds | Gestation period | Lactating period | Breeding season | Non-breeding season |
| Percent crude protein in feed mixture | 16 | 14 | 12 | 15 | 15 | 15 | 14 |

## Free-choice Feedings

The free-choice method of feeding is practical and economical where one is feeding out hogs for market.

Table 17 shows two protein supplement mixtures containing cottonseed meal which are recommended for both free-choice feeding and formulating complete mixtures.

After the pigs are 10 weeks old, they can be fed the protein supplement and grain free-choice in different compartments of a self-feeder.

Pigs intended for breeding should be taken off the free-choice method of feeding when they are 4 to 5 months old and be fed a complete mixture twice daily by hand. The condition of the breeding animals can be controlled better by hand feeding during the development period of the animal.

Milo or corn with either protein supplement no. 1 or no. 2 may be fed free-choice in self-feeders to growing-fattening pigs after the pigs have reached 40 pounds live weight, or after they are 10 weeks old.

For brood sows, gilts and herd boars, one may use a mixture containing supplement no. 2 as follows:

MIXTURE A

| | |
|---|---|
| Ground milo | 63 pounds |
| Wheat shorts | 20 pounds |
| Supplement no. 2 | 17 pounds |
| Total | 100 pounds |

Mixture A contains 15 percent crude protein and 5 to 6 pounds of this mixture per sow daily should give good results during the gestation period. After farrowing and being brought to a full feed gradually, sows with 8 pigs will require 11 to 12 pounds of the mixture daily per sow. Green pasture should be provided for brood sows during the gestation and lactating periods and for herd boars. If the green pasture is excellent, mixture A can be changed to only 10 pounds of supplement with 27 pounds of wheat shorts. This change should not be made, however, unless the pasture is plentiful, green and tender. Mature pasture or forage plants are of little use to swine. Ground oats may replace all or a part of the wheat shorts in mixture A.

Where one would like a mixture for the brood sow or herd boar and would prefer supplement no. 1, the following 15 percent crude protein mixture may be used:

MIXTURE B

| | |
|---|---|
| Ground milo | 59 pounds |
| Supplement no. 1 | 16 pounds |
| Wheat shorts | 15 pounds |
| Ground oats | 10 pounds |
| Total | 100 pounds |

This mixture B should be used where good green pasture is available for the breeding herd.

Where no green pasture is available, mixture C is recommended.

MIXTURE C

| | |
|---|---|
| Ground milo | 53 pounds |
| Supplement no. 1 | 14 pounds |
| Wheat shorts | 15 pounds |
| Ground oats | 10 pounds |
| Green alfalfa meal | 8 pounds |
| Total | 100 pounds |

If the sows have access to a good green forage crop, mixture B may be changed to one containing 65 pounds of ground milo, 15 pounds of wheat shorts, 10 pounds of ground oats and 10 pounds of supplement no. 1.

TABLE 17. USE OF COTTONSEED MEAL IN PROTEIN SUPPLEMENTS FOR SWINE RATIONS

| Ingredients | Crude protein, % | Number 1[1] | Number 2[2] |
|---|---|---|---|
| | | Pounds | Pounds |
| Soybean meal | 44 | 35 | 37 |
| Cottonseed meal | 41 | 20 | 37 |
| Meat scraps | 50 | 20 | |
| Dehydrated alfalfa leaf meal | 20 | 20 | 19 |
| Ground limestone | | 2 | 4 |
| Salt | | 1 | 1 |
| Aurofac[3] | | 2 | 2 |
| Total | | 100 | 100 |

[1]Percent of total crude protein is 37.60.
[2]Percent of total crude protein is 35.25.
[3]Containing 1.8 grams of aureomycin and 1.8 grams of vitamin $B_{12}$ per pound.

## ACKNOWLEDGMENTS

The authors are indebted to the Educational Service, National Cottonseed Products Association, Inc., Dallas, Texas for grants-in-aid; Buckeye Cotton Oil Co., Memphis, Tennessee, for furnishing degossypolized cottonseed meal; Southern Regional Research Laboratory, U. S. Department of Agriculture, for supplies of special processes of cottonseed meals; and to Otto P. Seeman, herdsman, for his efficient assistance in the feeding of the experimental animals.

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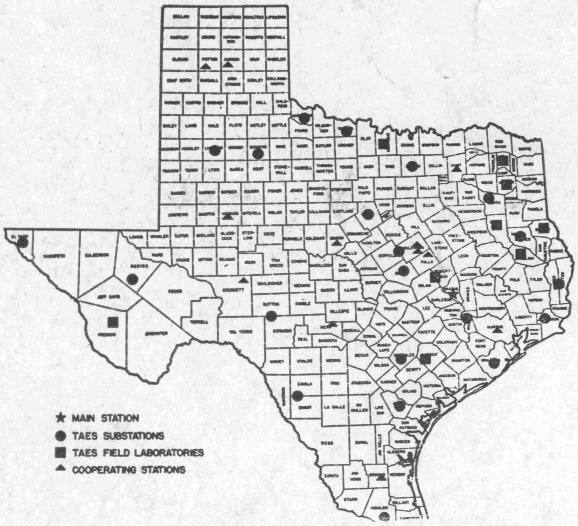


Location of field research units of the Texas Agricultural Experiment Station and cooperating agencies

# State-wide Research

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**The Texas Agricultural Experiment Station is the public agricultural research agency of the State of Texas, and is one of ten parts of the Texas A&M College System**

## ORGANIZATION

IN THE MAIN STATION, with headquarters at College Station, are 16 subject-matter departments, 2 service departments, 3 regulatory services and the administrative staff. Located out in the major agricultural areas of Texas are 21 substations and 9 field laboratories. In addition, there are 14 cooperating stations owned by other agencies. Cooperating agencies include the Texas Forest Service, Game and Fish Commission of Texas, Texas Prison System, U. S. Department of Agriculture, University of Texas, Texas Technological College, Texas College of Arts and Industries and the King Ranch. Some experiments are conducted on farms and ranches and in rural homes.

## OPERATION

THE TEXAS STATION is conducting about 400 active research projects, grouped in 25 programs, which include all phases of agriculture in Texas. Among these are:

- Conservation and improvement of soil
- Conservation and use of water
- Grasses and legumes
- Grain crops
- Cotton and other fiber crops
- Vegetable crops
- Citrus and other subtropical fruits
- Fruits and nuts
- Oil seed crops
- Ornamental plants
- Brush and weeds
- Insects
- Beef cattle
- Dairy cattle
- Sheep and goats
- Swine
- Chickens and turkeys
- Animal diseases and parasites
- Fish and game
- Farm and ranch engineering
- Farm and ranch business
- Marketing agricultural products
- Rural home economics
- Rural agricultural economics
- Plant diseases

Two additional programs are maintenance and upkeep, and central services.

*Research results are carried to Texas farmers, ranchmen and homemakers by county agents and specialists of the Texas Agricultural Extension Service*

**AGRICULTURAL RESEARCH seeks the WHATS, the WHYS, the WHENS, the WHERES and the HOWS of hundreds of problems which confront operators of farms and ranches, and the many industries depending on or serving agriculture. Workers of the Main Station and the field units of the Texas Agricultural Experiment Station seek diligently to find solutions to these problems.**

*Today's Research Is Tomorrow's Progress*