

SOYBEAN OIL MEAL AS A PROTEIN SUPPLEMENT IN
SWINE FEEDING RATIONS

by

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
THE NEED OF PROTEIN SUPPLEMENTS IN SWINE FEEDING RATIONS	3
PROTEIN SUPPLEMENTS SUITABLE FOR SWINE FEEDING PURPOSES	6
SOYBEAN PRODUCTION IN THE UNITED STATES	20
SOYBEAN PRODUCTION BY STATES, 1938	23
SOYBEAN OIL MEAL PRODUCTION IN THE UNITED STATES	24
METHODS OF PRODUCING SOYBEAN OIL MEAL	25
REVIEW OF EXPERIMENTS AT VARIOUS STATIONS OTHER THAN KANSAS IN THE USE OF SOYBEAN OIL MEAL AS A PROTEIN SUPPLEMENT IN SWINE RATIONS	30
COMPILATION AND INTERPRETATION OF RESULTS SECURED AT THE KANSAS STATION FROM FEEDING SOYBEAN OIL MEAL AS A PROTEIN SUPPLEMENT IN SWINE RATIONS	44
CONCLUSION	58
ACKNOWLEDGMENT	58
LITERATURE CITED	59

INTRODUCTION

Early investigators in animal nutrition recognized the fact that certain minimum amounts of protein must be supplied to animals in their food. As early as 1864, Wolff in his feeding standards stated the amounts of digestible crude protein thought to be necessary for the various classes of livestock. Swine feeders soon realized the inefficiency of corn and other cereal grains as the sole feed for growing and fattening swine. The unsatisfactory results obtained from feeding corn and other cereal grains were attributed to the low quantity and quality of protein contained.

To overcome these deficiencies of the cereal grains, swine feeders began the purchase of commercial foodstuffs high in proteins to supplement the corn and other cereal grains. It was found that a comparatively large number of protein supplements were suitable for swine feeding purposes; depending mainly upon such factors as cost and availability. The suitable proteins may be listed under two heads, depending upon their origin as:

(a) Proteins of animal origin, which include tankage and related packing house by-products; by-products of the fisheries industry; and by-products of the dairy industry.

(b) Proteins of plant origin. This group includes the by-products of the milling industries as corn gluten feeds and wheat middlings; cottonseed meal, linseed oil meal, peanut oil meal, and soybean oil meal from the respective oil crushing operations.

The increased production of soybeans in the corn belt during the past two decades seemed to offer a home-grown protein supplement that could be included in the ration of swine. Upon the feeding of whole soybeans in quantities sufficient to balance the ration of growing and fattening pigs, soft pork was produced. Thus, soybeans proved unsatisfactory. By removing the oil from the soybean, it was found that a product remained (soybean oil meal) that could be used to supplement corn in swine rations without the danger of producing soft pork.

This study was undertaken to show the trends and methods of producing soybean oil meal and the results obtained at the various state experiment stations by the inclusion of soybean oil meal in the rations of swine.

A review of the results obtained at those stations in which soybean oil meal was fed as a protein supplement in swine rations was made; the results compiled and interpreted.

THE NEED OF PROTEIN SUPPLEMENTS IN SWINE FEEDING RATIONS

Of great importance in the work of the early investigators in animal nutrition was the knowledge gained of the functions of the various classes of foods in the body of animals. The knowledge of the chemical composition of the body of farm animals has served as a guide for the early workers in animal nutrition in formulating feeding standards for animals. In Table 1 the average body composition of swine at various degrees of development is shown.

Table 1. Body composition of swine (8).

Condition of fatness:	Weight at slaughter:	Body substance:	Components of body substance			
			Water	Protein	Fat	Ash
	: Pounds	: Pounds	: Per cent	: Per cent	: Per cent	: Per cent
Thin	: 106	: 100	: 56.3	: 14.9	: 25.8	: 3.1
Moderately fat	: 162	: 154	: 49.2	: 13.7	: 34.2	: 2.9
Fat	: 219	: 210	: 44.3	: 12.6	: 40.6	: 2.5
Very fat	: 230	: 219	: 41.4	: 10.5	: 45.9	: 2.3
Extremely fat	: 343	: 327	: 37.7	: 10.8	: 49.5	: 2.1

Once the animal leaves its mother's body, the substances to build these tissues must be supplied to it

through the foods eaten. Thus, the production of heat and energy, the supplying of material for repair of worn-out tissues, and the formation of new tissues (growth) become recognized as the function of the animal's food.

The primary food demand of any animal is for substances which will furnish energy for the body activities and heat to keep it warm. These demands are met principally by the carbohydrates (starches and sugars) and fats of the rations.

Protein is necessary for the growth of muscles and other protein tissues such as the vital organs and the muscles and for their repair. That none of the other food constituents can perform these functions, adds emphasis to the value of various supplementary feeds rich in proteins.

Morrison (15) showed that not only for proper growth in swine, but for economical fattening as well, swine rations must be fully balanced by the addition of a sufficient amount of an efficient protein supplement.

In commenting on the importance of protein supplements in swine rations, Carroll (6) stated that protein is most frequently the limiting factor in the ration of swine. This is due to the fact that the common farm grains and many of the by-products that are available carry too low a percentage of protein for best results in the rations for most classes of swine. He summarized the results of 23

tests at other state experiment stations to show the value of a protein supplement (tankage) to corn for fattening pigs. The results are summarized in Table 2.

Table 2. The value of a protein as a supplement to corn.

	: Light pigs:		Heavy pigs:		Light pigs:	
	: in dry lot:		: in dry lot:		: on pasture	
	: Corn :		: Corn :		: Corn :	
	: and :		: and :		: and :	
	: tank-:		: tank-:		: tank-:	
	: Corn :	age	: Corn :	age	: Corn :	age
Number of tests	: 6 :	6	: 8 :	8	: 9 :	9
Total pigs	: 24 :	29	: 69 :	69	: 77 :	79
Av. days in test	: 102 :	102	: 84 :	84	: 113 :	110
Av. initial weight, lbs.	: 63 :	62	: 132 :	134	: 52 :	52
Av. final weight, lbs.	: 116 :	196	: 223 :	267	: 161 :	199
Av. daily gain, lbs.	: .84 :	1.16	: 1.04 :	1.56	: .97 :	1.34
Av. daily ration:	: :		: :		: :	
Corn, lbs.	: 3.10 :	3.80	: 5.63 :	6.35	: 3.96 :	4.63
Tankage, lbs.	: ... :	.40	: ... :	.54	: ... :	.27
Feed for 100 lbs. gain	: :		: :		: :	
Corn, lbs.	: 581 :	350	: 537 :	410	: 409 :	345
Tankage, lbs.	: ... :	36	: ... :	34	: ... :	20
Corn saved by 100 lbs.	: :		: :		: :	
tankage	: ... :	642	: ... :	374	: ... :	320
	: :		: :		: :	

Figures for tankage were used in this table because such complete data are not available for other supplements. Any suitable protein supplements, however, would be expected to give similar results.

All investigations and experiments on the question indicate without exception that the common farm grains are much improved for swine by the addition of protein supple-

ments. Such supplements result in keener appetite, which means greater consumption of feed. The increased consumption of feed means increased rate of gain. Protein also reduces the feed requirement for each unit of gain (6).

PROTEIN SUPPLEMENTS SUITABLE FOR SWINE FEEDING PURPOSES

Mention has already been made of the economy of pork production and the nutritional advantages gained by including a protein supplement in the ration of swine. In the selection of a protein supplement suitable for swine feeding purposes, the pork producer has recourse to a variety of home-grown and commercial protein feeds. Protein supplements may be grouped into two general classes, depending upon the source from which they are derived, as protein supplements of animal origin and protein supplements of plant or vegetable origin.

As a general rule, supplements of animal origin, such as dairy by-products, tankage, and fish meal, have a higher supplementing value than those of plant or vegetable origin, such as the oil meals, gluten meals, and other cereal by-products. Investigations have shown that the differences in the value of the two classes of proteins are the result of the differences in the quality of proteins contained rather than to any differences in the amounts of proteins.

Smith (19) pointed out that the tissues of growing pigs are composed of various combinations of some 20 or more nitrogen-containing compounds known as amino-acids, and that these amino-acids serve as "building-stones" with which the pig constructs the tissues of growth. Most of the "building-stones" or amino-acids must be secured by the animal from the food which is consumed and digested. The supplements of animal origin are supposed to contain a larger number of these amino-acids than the supplements of plant origin. The animal supplements are therefore, superior to plant supplements in the pigs' ration. The principal protein supplements suitable for swine feeding purposes are given below.

Proteins of Animal Origin

Tankage. A by-product of the packing industry, tankage is the most widely used high-protein supplement that is now fed to hogs. High-grade tankage contains 60 per cent protein and 15 per cent mineral matter, both of which are utilized well by hogs (6).

Statistics showing the amount of tankage and related products which are produced in the United States are not available, but conservative estimates have placed the production of feeding tankage, including meatscraps, and meat and bone scraps, at approximately 400,000 tons annually

(19).

Fish meal. Fish meal is the general name used to designate quite a wide variety of fish products which are by-products of the fisheries industry. Differences in the raw material used and the methods employed in processing, cause variations in the composition of the different brands. Fish meal is high in protein as well as mineral matter; containing from 50 to 60 per cent protein and 15 to 25 per cent mineral matter (15). In addition, fish meal usually contains from 3 to 16 per cent fat.

One objection to the feeding of fish meal to swine is the belief that the meal may impart a fish taste to the pork. This objection is overcome by feeding a good quality meal in amounts sufficient to balance the ration.

The production of fish meals and related products in the United States and Alaska for 1939 was estimated to have been approximately 115,062 tons.

Skim milk and buttermilk. As a protein supplement, skim milk and buttermilk excel any other single feed; both are rich in high-quality proteins and are also high in calcium and phosphorus. Feeding tests have shown that skim milk and buttermilk are about equal in value in the ration of swine. However, care must be taken to see that the buttermilk does not contain too much wash-water. In order to prevent the spread of tuberculosis and contagious abortion

in swine, both products should be pasteurized before being fed to swine.

According to estimates by Smith (19) the annual production of semi-solid buttermilk is 14,000 tons; buttermilk, 128,000 tons; and skim milk, 1,524,000 tons. The latter two being reduced to 15 per cent moisture basis.

Whey. Whey, a by-product of the cheese-making industry, contains from .8 to .9 per cent protein, mostly milk albumin. The protein in whey is of high quality and effectively supplements the cereal grains in swine rations. Because of the small percentage of protein in whey, it has proved more effective as a supplement to corn when fed to pigs over 100 pounds, as compared with younger, less-developed pigs. Growing pigs, under 100 pounds, require more protein than is generally supplied by this supplement. Whey is usually given a value of about one-half that of skim milk or buttermilk. The bulkiness of whey makes it necessary to feed it close to the area of production.

Whole milk. The high value of butterfat for human food, prohibits the profitable feeding of whole milk to swine. The high fat content of whole milk makes it somewhat unsatisfactory as a feed for young pigs, as digestive disorders often result. Morrison (15) gave the results of a test at the Utah Station, in which whole milk was given a

value about twice that of skim milk when the two were fed to pigs.

Proteins of Plant or Vegetable Origin

Wheat standard middlings or shorts. Wheat standard middlings are the by-product resulting from the milling of wheat; consisting mostly of fine particles of bran and germ. Standard middlings average 17.4 per cent in protein, 6.8 per cent in fiber, and 5.5 per cent in fat.

For best results, wheat middlings should be fed in combination with another protein supplement, preferably of animal origin. In the results of tests reported by Carroll (6) wheat middlings proved to be of less value for light pigs than for those of heavier weights.

About 2,400,000 tons of middlings are produced annually for feeding purposes in the United States. Although they are fed to all classes of livestock, wheat middlings rank among the most popular feeds for all classes of swine.

Linseed oil meal or linseed meal. Linseed meal is the product obtained when flaxseed is coarsely ground, heated, and pressed in hydraulic presses. The product remaining after the oil has been pressed from the seed is known as linseed cake, and may be ground into linseed meal.

Like the by-products of the wheat milling industry,

linseed meal is an excellent protein supplement in the ration of swine when fed in combination with a protein of animal origin. In the trio or Wisconsin supplemental mixture, developed by Morrison and associates at the Wisconsin Station, a mixture of 50 pounds of tankage or fish meal, 25 pounds of linseed meal, and 25 pounds of ground or chopped alfalfa hay are used. The quality of the protein found in linseed meal is not of the quality to correct the deficiencies of the cereal grains.

Approximately 537,000 tons of linseed meal are produced in the United States annually, but because of its popularity for other classes of livestock, a relatively small amount is available for swine feeding purposes. The wide demand for linseed meal usually supports the price above a level where its general use as a swine feed tends to be prohibitive.

Cottonseed meal. By removing the hull from the cottonseed, the cottonseed kernel is obtained. The kernel is crushed, cooked by steam, put between cloths, and placed in hydraulic presses to remove as much of the oil as possible. The product remaining in the presses is cottonseed cake. The cake may be ground into meal or pressed into various sizes of pellets for sale as livestock feeds.

The protein content of cottonseed meal ranges from 36

per cent to 45 per cent. It is designated and sold according to its protein content. Like most of the seed by-products, cottonseed meal is deficient in calcium and sodium chloride, but it is especially rich in phosphorus.

Because of the danger of "poisoning", the use of cottonseed meal in unlimited amounts in swine rations has not been general. When fed to hogs on good pasture, the toxic effects are lessened. The toxic factor thought to be responsible for cottonseed meal poisoning is a compound called gossypol.

As the results of feeding tests with cottonseed meal, Hale of the Texas Station, concluded that cottonseed meal may be fed to all classes of swine when the amount in the ration does not exceed 9 to 10 per cent. Good results were secured when cottonseed meal was fed in combination with a protein of animal origin. When the animal supplement makes up less than one-half the protein mixture, a calcium supplement should be fed.

In 1937 the production of cottonseed cake and meal amounted to 2,830,400 tons. The average price per ton for 41 per cent protein (at Memphis) for this same year was \$22.36 (19). Just what percentage of the total production was used for swine feeding purposes, is uncertain. Because of its relative low price, cottonseed meal can economically

make up a portion of the protein supplement of swine rations.

Corn gluten feed and corn gluten meal. Corn gluten feed is a by-product of the cornstarch manufacturing industry. It is made up of that part of the corn kernel which is left after the starch and germ are removed. Corn gluten feed averages about 26.4 per cent protein, 7.1 per cent fiber, 48.4 per cent nitrogen-free extract, and 2.5 per cent fat (15).

Corn gluten meal is similar to corn gluten feed except that it does not contain the corn bran, and is therefore, higher in protein content. It averages about 43 per cent protein.

Neither corn gluten meal nor corn gluten feed has proved effective as the sole protein supplement, as they do not correct the protein deficiencies of corn, are somewhat bulky, and are not very palatable. When used as supplements to corn with pigs on pasture, fairly satisfactory results were secured at the Nebraska Station. For best results, it is suggested that the feeds be fed in combination with a protein of animal origin and a good mineral mixture. For pigs in dry lot, a good quality legume hay should be included in the ration.

Peanuts, peanut oil meal, and peanut oil feed. In the

peanut-producing areas of the United States, over a third of the peanut acreage is harvested by allowing the hogs to graze the fields. The remaining acreage, which is harvested for the peanut, is later grazed to allow the hogs to salvage those resulting from incomplete harvesting. Peanuts are an excellent supplement for swine, except that they produce soft pork, when consumed in too large quantities, and are low in calcium. The soft pork is objectionable to the packers, and hogs marketed from peanut-producing areas are subject to dockage. To avoid the production of soft pork, peanuts should be fed only to breeding stock and pigs below 85 pounds in weight; the latter, after reaching this weight, should be finished on a ration that will produce hard pork.

According to Morrison (15) peanuts in the shell contain an average of 24.9 per cent protein, 36.2 per cent fat, and 17.5 per cent fiber. The protein in peanuts is of good quality.

Peanut oil meal is the product obtained when the oil is pressed from hulled peanut kernels. The product obtained when the whole peanut, including the hull, is pressed is known as peanut oil feed. The average composition of peanut oil meal is 40 per cent protein and 7 per cent fiber. Peanut oil feed differs from peanut oil meal in that

it is lower in protein content and higher in fiber; whole pressed peanuts or peanut oil feed contains about 25 per cent protein and 23 per cent fiber.

For pigs on good pasture or for well-grown pigs in dry lot, peanut oil meal is satisfactory as the sole protein supplement. For young pigs in dry lot, peanut oil meal should be fed in combination with an animal protein.

Peanut oil feed, as shown above, is lower in protein than peanut oil meal, due to the increase in fiber content. Its value, in relation to peanut oil meal, will be determined by the relative amount of fiber.

Approximately 92,000 tons of peanut oil meal and peanut oil feed were produced in the United States in 1937.

Velvet beans and velvet bean feed. The velvet bean is a legume especially adapted to the sandy soil of the South Atlantic States. The velvet bean has long vines and is usually grown in combination with corn for support of the vine. The combination crop is generally harvested by first harvesting the better and larger ears of corn and allowing the remaining beans and corn to be grazed or hogged off. The beans are rich in protein (18 per cent) and form a well-balanced ration when fed with corn (17).

Morrison (15) was of the opinion that the velvet beans, regardless of the form in which they are fed, are unsatis-

factory as feed for all classes of swine. Swine on velvet beans have been known to suffer from digestive disturbances such as vomiting and diarrhea.

Legume pastures and hays. For economical pork production, good pastures are necessary. Pastures provide the vitamins essential for thrifty and vigorous development; they supply the mineral elements (calcium and phosphorus) necessary for bone development, and they provide proteins that efficiently supplement the cereal grains. In addition, pastures afford the opportunity of exercise and exposure to sunlight, and provide sanitary surroundings.

Legume pastures, especially alfalfa, are valuable as a source of protein for swine. Carroll (6) of the Illinois Station, stated that from 50 to 100 per cent of the protein supplement will be saved when hogs are on good pasture. He added that all of the supplement will be saved in feeding mature, dry sows and growing pigs on light grain rations; and as much as 50 per cent of the supplement will be saved in the case of young pigs and fattening shoters on full feed. Aubel (5) reported the results of an experiment in which one group of pigs received a ration of corn, alfalfa pasture, and one-fourth pound of tankage, and another group, corn and alfalfa pasture. The pigs which received the tankage in addition to the alfalfa pasture and corn,

made 80 per cent greater daily gains and at a cost 9 per cent less than the group of pigs fed the corn and alfalfa pasture ration minus the tankage.

Experiments indicate that legume hay of good quality and texture may be used to eliminate a portion of the commercial protein supplement in rations of swine. In a test at the Kansas Station, it was found that pigs receiving alfalfa hay in addition to corn and tankage made 25 per cent greater daily gains on 10 per cent less corn than pigs receiving corn and tankage without alfalfa hay. Smith (19) held that good quality alfalfa hay can replace the tankage in the ration of pregnant sows during the winter, provided the sows will consume from one and one-half to two pounds daily.

Protein mixtures. Generally speaking, the proteins of animal origin are regarded as being higher in price and more efficient than those of animal origin. With the idea of securing the advantages gained by feeding an animal protein more economically, a number of protein mixtures were devised and tested at some of the state experiment stations.

The usual procedure was to replace from 50 to 75 per cent of the animal protein (tankage or fish meal) with equal amounts of protein of vegetable origin. A mixture developed by Morrison and associates at the Wisconsin Sta-

tion was composed of 50 pounds tankage, 25 pounds ground or chopped alfalfa or other legume hay, and 25 pounds of linseed meal. This mixture, known as the trio mixture, the trinity mixture, or the Wisconsin mixture, has received wide approval among swine feeders. Such a mixture proved especially good for pigs in dry lot, as it provided vitamin D, minerals, and good quality proteins in an economical manner.

Other experiments have proved that fish meal may be substituted for the tankage, and that soybean oil meal or cottonseed meal may replace the linseed meal in the trio mixture. Various other combinations including a larger number of proteins have been devised, but it is generally thought that the extra cost required in mixing and handling is not justifiable. Aubel (5) suggests limiting the mixture to three feeds, in which 50 to 75 per cent of the animal protein is replaced by equal amounts of plant protein.

Soybeans. The production of soybeans in the United States has shown marked increase the past ten years. The most outstanding increase has been in the area known as the Corn Belt.

Soybeans are relatively high in protein (36.9 per cent) and fat (17.2 per cent). When fed as the sole protein supplement in amounts sufficient to balance the ration of growing and fattening pigs, soft, oily, unattractive car-

carcasses or "soft pork" are produced. The soft carcasses are unattractive and must be retailed at reduced prices. There is no satisfactory method of foretelling whether a carcass will "dress out" as a hard or a soft carcass, and hogs suspected of having been fed on soybeans are bought by the packers at reduced prices to the producers.

Soybeans generally prove satisfactory as the only protein supplement to corn for brood sows (15).

Another limitation of soybeans as the only protein supplement is the fact that they are low in minerals, especially calcium. They are also lower in phosphorus than the animal proteins.

Smith (19) in a summarized report of 12 experiments conducted at the Ohio and Indiana Stations, in which raw soybeans were compared with cooked soybeans, found that cooking the beans had the effect of increasing the rate of gain by more than 30 per cent. The cooking of the beans had the added effect of doubling their value when measured by the economy of gains. Cooked beans are more palatable to pigs and should never be fed free-choice, as they are likely to be consumed in amounts too great for satisfactory carcasses or economical gains.

Soybean oil meal. After most of the oil has been removed from the soybean, the residue after grinding is soy-

bean oil meal.

Soybean oil meal is much superior to the original soybean as a protein supplement in swine rations. It is higher in protein (averaging 44.3 per cent) and lower in fat (5.7 per cent). Because of its low fat content, soybean oil meal does not have the effect of producing soft pork when fed to fattening pigs in amounts sufficient to balance the ration.

Like soybeans, soybean oil meal is deficient in calcium and phosphorus; and when it is fed as the only protein supplement or in combination with another supplement of plant origin, a mineral mixture should be included in the ration.

SOYBEAN PRODUCTION IN THE UNITED STATES

American literature indicates that the soybean may have been grown in the United States before the year 1804. However, its economic importance was not appreciated at this early date, and its culture was limited to scholars who were interested in it for its botanical values (16).

In the last decade of the nineteenth century, the state agricultural experiment stations and the United States Department of Agriculture began to import varieties from the Orient. Increase of acreage and production in the

United States was greatly stimulated by these importations and the improvements made upon the Oriental varieties.

The acreage of soybeans grown for all purposes has shown marked increases during the past decade, advancing from 2,439,000 acres in 1928 to 7,789,000 acres in 1938. Of the 2,439,000 acres grown in 1928, 579,000 acres were harvested for beans as compared with 2,898,000 acres harvested for beans from the 1938 crop of 7,789,000 acres. While the total acreage grown for all purposes during this decade increased over 313 per cent, the total acreage harvested for beans increased over 372 per cent during the same period.

Due to improved varieties, selection, and better cultural methods, the average yield per acre was increased from 13.6 bushels in 1928 to 19.9 bushels in 1938. Total seed production in the United States in 1928 amounted to 7,880,000 bushels, with an average farm value of \$1.80 per bushel, or a total farm value of \$14,953,000. By 1938 the total seed production increased to 57,665,000 bushels, with an average farm value of 76 cents per bushel, or a total farm value of \$43,768,000.

Table 3. Soybeans: acreage, yields, production, price per bushel, and total farm value, United States, 1928 and 1938 (2).

Year	Total acreage	Acreage harvested	Average yield	Production	Price	Total farm value
	Bushels	Acres	Bushels per acre	Bushels	Dollars	Dollars
1928	2,439,000	579,000	13.6	7,880,000	1.90	14,963,000
1938	7,789,000	2,898,000	19.9	57,665,000	.76	43,768,000

Table 4. Soybeans: acreage, yields, and production for the ten leading states in 1938 (2).

State	Total acreage	Acreage harvested for beans	Yields per acre	Total yield
	Acres	Acres	Bushels	Bushels
1. Illinois	2,118,000	1,356,000	23.5	31,866,000
2. Indiana	828,000	431,000	19.5	8,404,000
3. Iowa	950,000	294,000	19.5	5,733,000
4. Ohio	445,000	253,000	21.0	5,313,000
5. North Carolina	515,000	155,000	13.0	2,015,000
6. Arkansas	306,000	64,000	10.0	640,000
7. Missouri	320,000	58,000	10.5	609,000
8. Michigan	77,000	35,000	16.0	560,000
9. Mississippi	560,000	56,000	8.5	476,000
10. Delaware	41,000	25,000	16.0	400,000
United States	7,789,000	2,898,000	19.9	57,665,000

SOYBEAN PRODUCTION BY STATES, 1938

The acreage and production of soybeans in 1938, were concentrated chiefly in the North Central States (Corn Belt) of the United States. Illinois, Indiana, Iowa, Missouri, and Ohio produced 51,316,000 bushels (90 per cent) of the 57,665,000 bushels harvested in this year; 50 per cent of the total being harvested in Illinois alone. (See Table 4). Considerable acreage in the northern half of the Cotton Belt was devoted to the production of soybeans. Soybean production is limited almost entirely to the eastern two-fifths of the United States.

Considerable variation in the yields per acre was noticed between the major producing states. Yields were heaviest in Illinois, with an average of 23.5 bushels per acre, as compared with an average of five bushels per acre in Texas. The five highest producing states in 1938, in order of their rank, were Illinois, Indiana, Iowa, Ohio, and North Carolina.

SOYBEAN OIL MEAL PRODUCTION IN THE UNITED STATES

Soybeans grown in the United States, when milled or crushed, yield about 80 per cent of their weight in a high-protein product known as soybean oil meal or soybean oil cake. Soybean oil meal and soybean oil cake are used primarily as a concentrated livestock and poultry feed and also for making vegetable glues and plastics (20). Another product of economic importance obtained from the crushing of the soybean is soybean oil. The soybean yields 14-16 per cent of its weight in this edible oil.

In the ten-year period between 1927-28 and 1937-38, soybean oil meal production in the United States increased in volume over 55 times. There were 21,192 tons of soybean oil meal produced from crushing 883,000 bushels of beans from the 1927-28 crop. After crushing 44,470,000 bushels of the 1937-38 soybean crop, the soybean oil meal pro-

duction reached the phenomenal figure of 1,167,280 tons.*

Johnson estimated that 95 per cent of the soybean oil meal produced in the United States is utilized as feed for livestock and poultry (12). These figures would indicate that the American farmers used approximately 1,109,000 tons of this protein-rich feed in their livestock and poultry rations.

METHODS OF PRODUCING SOYBEAN OIL MEAL

Removal of the oil from the whole soybean yields two products of vast economic importance. The oil derived from the soybean finds use in the paint, varnish, and lacquer industry; in the manufacture of soaps and edible oils, as well as many other commercial uses. The product remaining after the oil has been removed, soybean oil meal, finds its principal use in the livestock feeding industry.

Soybean oil meal production naturally results in the production of soybean oil as they are both from the same product (soybean seed) in the same operation. However, in this discussion, the main emphasis is placed upon the production of the meal.

*Calculated: Soybeans = 60 lbs. per bushel, yielding 80 per cent soybean oil meal.

In the production of soybean oil meal (and soybean oil), three different methods are employed. The first of these methods is the hydraulic or "old process". The second and perhaps the most widely used method is known as the ex-peller process. A third, and more recent method of extracting the oil from the soybean is the solvent process. The first two processes involve physical operations or force, and are often referred to, collectively, as the expression methods. The last process involves the use of chemicals.

Each of the three methods has its advantages and disadvantages. The question as to which product - the oil or the meal - is of greater value to the processor usually determines which method will be employed in the processing of the beans.

The Hydraulic or "Old Process"

In the hydraulic press method, the cleaned seeds are first broken or cracked so as to facilitate the crushing of the beans. The cracked beans are then passed over a series of rollers. The beans are crushed by the rollers into finely-ground particles ready for the cooking operation.

The ground beans are cooked in steam-jacketed cylinders for three-fourths to one and one-half hours. The moisture within the cylinders is carefully controlled by either in-

troducing steam into the cylinders or exhausting steam by means of fans (11).

The cooked meal is removed from the cookers in batches of about 20 pounds and put into boxes where it is pressed into compact cakes by a pressing ram. The product is transferred from the cake box or cake former to the cake press. In the cake press the product is subjected to pressures up as high as 4000 pounds per square inch. This pressure forces out the oil, which is collected in troughs mounted on the sides of the press. The cake remaining in the press after the oil is removed may be bagged and sold as soybean oil cake; or it may be ground and sold as soybean oil meal.

In the hydraulic method, the meal obtained contains about 6 per cent of oil (15) and is well cooked. The resulting oil is a hot-pressed oil and is therefore, unsuited for many industrial purposes.

The Expeller Process

The bulk of the soybean oil meal is produced by the expeller method, in which the oil is pressed from the cracked beans under (heat and) pressure. In this method, the beans are crushed and dried (the moisture content is reduced to 3 per cent or less). The dried beans are crushed by rol-

lers and finally placed in a device that resembles and operates on the same principle as a meat grinder. This apparatus is known as the expeller.

As the beans are forced through the expeller by a powerful screw or worm, considerable pressure and heat are developed. The pressure expels the oil, along with fine particles of the bean, through the gratings or perforations of the expeller. The heat thoroughly cooks the meal.

Soybean oil meal produced by the expeller process contains about 6 per cent oil. The meal has a roasted-nut odor and flavor, and is very palatable to livestock.

The quality of the oil obtained is superior to that obtained by the hydraulic method. The oil is well-suited for the manufacture of paints and varnishes.

The Solvent Process

The solvent method of soybean oil meal production is one which gives the maximum benefits to the processor primarily interested in the oil. However, recent improvements in this method have made it possible to produce a meal of excellent quality.

In the solvent method the oil is extracted by chemicals or solvents. The seeds are rolled into flakes so as to break the outer coatings. The flaked seed is then treat-

ed with a fat solvent to dissolve the oil.

To thoroughly remove all traces of the solvent, the meal is steamed. This steaming also cooks the meal, which has the effect of rendering it more palatable. Because of the low temperature to which this meal is subjected during the processing, it is white in color, and is generally toasted or browned after having the oil removed. Toasting the solvent meal imparts to it a nutty odor and flavor, thus rendering it more palatable to livestock.

Solvent soybean oil meal contains approximately 1.5 per cent oil.

The oil is separated from the solvent by distilling off the latter.

A large number of commercial substances suitable as solvents in the extraction of the oil are available. The main prerequisites of a solvent are inflammability and economy. A special cut of gasoline is the most commonly used inflammable solvent. Ordinary motor fuels are unsuitable for this purpose.

REVIEW OF EXPERIMENTS AT VARIOUS STATIONS OTHER THAN
KANSAS IN THE USE OF SOYBEAN OIL MEAL AS A PRO-
TEIN SUPPLEMENT IN SWINE RATIONS

A vast amount of the research work being done in animal husbandry at the various state experiment stations is devoted to the scientific and economical feeding of livestock. Any feed showing possibilities of meeting the nutritional requirements of a given class of livestock on an economical basis is due to receive scientific consideration from these experiment stations. Soybean oil meal has shown these possibilities and has been receiving the careful consideration of students of animal nutrition and livestock feeders.

In order to determine the value of soybean oil meal as a protein supplement in swine feeding rations, a number of feeding trials and experiments have been conducted by the different experiment stations. This is especially true of those stations located in the Corn Belt area.

A brief review of the work done by the stations located in this area follows. The review must not be considered as complete. Many stations, other than the ones mentioned, have made similar tests but the results are not in published form.

Studies at the North Carolina Station

As the first production of soybean oil meal took place in North Carolina, it is approximate that mention of the work at this station be made first. Most of the feeding trials at this station were designed to show the comparison between soybean oil meal and fish meal as protein supplements to corn. Menhaden fish meal, with an average digestible protein content of 45.6 per cent, was used in all experiments. The soybean oil meal used was processed by the hydraulic or "old process" method. It exhibited a brown color, with a nutty taste and odor. The digestible protein content averaged 37.6 per cent. A mineral mixture was fed in all trials and the feeds were self-fed free-choice.

The results of three trials in which soybean oil meal was compared with fish meal as the protein supplement for pigs over 100 pounds showed the following results: (1) Soybean oil meal was not as valuable as the fish meal when self-fed free-choice, (2) pigs allowed free-choice soybean oil meal consumed more than was required to balance the ration, and (3) fish meal gave faster as well as more economical gains (10).

A summary of four feeding trials at the same station in which one lot of pigs was fed fish meal and a second lot

was fed equal parts of soybean oil meal and fish tankage as the protein supplement showed the following results: (1) The pigs ate more of the supplement mixture than was required to balance the ration, (2) the daily gains per pig were practically identical for both groups, (3) the pigs receiving the fish meal made more economical gains, (4) the pigs receiving the protein mixture consumed more fish meal, although it made up but one-half of the protein mixture (5). The soybean oil meal had the effect of replacing an equal amount of the cheaper feed (corn) rather than replacing a part of the more expensive fish meal.

The gains made by both groups of pigs were excellent. These results showed no advantage in replacing 50 per cent of the fish meal with soybean oil meal.

A similar trial in which the protein mixture consisted of one-third fish meal, one-third cottonseed meal, and one-third soybean oil meal, showed this mixture to be slightly superior to the fish meal in daily gains and economy of gain.

With pigs on soybean pasture, the North Carolina workers found that soybean oil meal compared more favorably with fish meal as the protein supplement for fattening pigs. The results of one feeding trial under the above conditions showed identical daily gains. The pigs receiving the fish

meal made their gain at a cost slightly less than those receiving the soybean oil meal.

The results obtained showed that soybean oil meal is a more satisfactory supplement for pigs on pasture than in dry lot.

Feeding Trials at the Missouri Station

Weaver (21) reported the results of two investigations with the view of finding out methods of feeding which would give maximum returns from the use of soybean oil meal when used to supplement corn fed to fattening hogs on pasture.

The pigs used in the experiment averaged about 47 pounds when started on the test. One lot received 16 parts corn and 1 part tankage; a second lot received 8 parts corn and 1 part soybean oil meal; and a third lot was fed a mixture of 24 parts corn, 1 part tankage, and one part soybean oil meal. Each lot was full fed (by hand) on alfalfa pasture. No mineral mixture was included in the ration.

The tankage used was guaranteed to contain 60 per cent crude protein. The soybean oil meal was produced by the expeller process and contained 46 per cent crude protein. Shelled corn was used throughout the experiment.

In summarizing the results of the experiments, Weaver stated: "(1) No apparent advantage resulted from combining

protein supplements either as to rate or economy of gain in terms of pounds of feed required to produce 100 pounds gain, (2) when used as a supplement to corn, tankage was slightly superior to soybean oil meal, (3) as a supplement to corn fed fattening pigs on alfalfa pasture, one pound of tankage was as efficient as two pounds of soybean oil meal."

While no work was reported from the Missouri Station on the value of adding a mineral mixture to a ration of corn and soybean oil meal for pigs on alfalfa pasture, results obtained by adding a mineral mixture to a ration of corn and soybeans showed such a ration to be superior to corn and soybeans alone, but inferior to corn and tankage or corn, soybeans, and tankage. Since soybean oil meal (as well as soybeans) is low in minerals, it seems safe to conclude that results similar to those obtained by the addition of a mineral mixture to soybeans and corn would exist when a mineral mixture is added to a ration of corn and soybean oil meal.

Minnesota Trials

Ferrin (9) of the Minnesota Station conducted trials in which expeller, solvent, and hydraulic processed soybean oil meal were compared with tankage as the protein supplement for pigs self-fed in dry lots. The pigs were divided into

four lots of 9 pigs each and fed for 90 days. The pigs were fed shelled corn and the following protein mixture.

Lot 1. Expeller soybean oil meal, 75 per cent; alfalfa meal, 10 per cent; mineral mixture, 15 per cent.

Lot 2. Solvent soybean oil meal, 75 per cent; alfalfa meal, 10 per cent; mineral mixture, 15 per cent.

Lot 3. Hydraulic soybean oil meal, 75 per cent; alfalfa meal, 10 per cent; mineral mixture, 15 per cent.

Lot 4. Tankage, 85 per cent; alfalfa meal, 10 per cent; mineral mixture, 5 per cent.

The summarized results showed the following results:

(a) The tankage-fed pigs gained an average of 0.1 pound more per head daily than the pigs receiving the soybean oil meals, (b) on the basis of rate of gain or feed consumed per 100 pound gain, all the soybean oil meals showed striking similarity, (c) the tankage-fed pigs had keener appetites as they consumed one-third pound more total feed daily per pig than the average of the three lots receiving soybean oil meal, and (d) the soybean oil meals were about as economical a source of protein as the tankage.

Iowa Feeding Trials

Workers at the Iowa Station (7) conducted experiments to determine the influence of soybeans and soybean oil meal upon the gains, feed requirements, and character of the fat when fed to growing and fattening pigs on rape pasture. The pigs were divided into four groups, and each group further divided into lots. One group consisting of only one lot, received no protein supplement. A second group (one lot) was self-fed tankage. The third group consisting of five lots, received cracked soybeans on the following levels: (a) Free choice, (b) 5 per cent of the grain ration, (c) 7.5 per cent of the grain ration, (d) 10 per cent of the grain ration, and (e) 20 per cent of the grain ration. The fourth group (one lot) was fed expeller soybean oil meal at the level of 10 per cent of the grain ration.

Cracked or shelled corn was used in all lots and was mixed in the various proportions with the protein supplement and self-fed or it was self-fed as a mixture with the protein supplement. A mineral mixture, self-fed, was available at all times.

The pigs were fed from an average weight of 73 pounds to a weight of 225 pounds.

The results showed that the tankage-fed pigs required

five days less time to reach 225 pounds than did the pigs receiving soybean oil meal. The differences in daily gains were almost insignificant when soybean oil meal was compared with tankage. The pigs receiving the soybean oil meal required 10 pounds less total feed to make 100 pounds gain than did those receiving tankage. The soybean-fed pigs compared favorably with the other groups in all phases of the feeding trials. However, upon slaughter, the carcasses of those receiving soybeans free-choice or as much as 20 per cent of the ration graded from medium soft to very soft in firmness.

Nebraska Feeding Trials

In the summer of 1935, three hog feeding trials were conducted at the Nebraska Station (13). The purpose of the trials were (a) to determine whether simple protein mixtures might be used with corn to increase either the rate or efficiency of gain as compared with tankage, (b) to compare linseed, cottonseed, and soybean oil meals when fed to fattening pigs receiving corn and tankage in dry lot, and (c) to compare various rations for full-feeding pigs on sudan grass.

In the first experiment in which simple protein mixtures were compared with tankage, the pigs averaged 104

pounds at the start of the experiment and were self-fed in dry lot for 75 days. The supplement mixture consisted of 2 parts tankage, 1 part alfalfa meal, and 1 part of either linseed meal, soybean oil meal, cottonseed meal, or corn gluten meal. The various mixtures were fed against tankage as the only protein supplement.

The experiment showed the protein mixtures to be more palatable than straight tankage; the mixtures also increased the consumption of corn. According to this test, wherever a mixed supplement was fed, greater gains were made than when tankage was the sole supplement; also less corn and total feed were required to make 100 pounds of gains.

In an 85-day feeding trial with pigs in dry lot, cottonseed meal, linseed meal, or soybean oil meal proved effective in replacing 50 per cent of the tankage in the ration.

A test with full-feeding pigs on sudan grass showed no advantage in replacing 50 per cent of the tankage in the ration with either cottonseed meal, linseed meal, or soybean oil meal.

Indiana Feeding Test

In the summer of 1936, the Indiana Agricultural Experiment Station (14) conducted the third in a series of trials to determine the relative efficiency of expeller process and solvent process soybean oil meal as protein supplements fed with corn and minerals to growing-fattening hogs in dry lots. Tankage was fed as a check against the soybean oil meals.

According to the results obtained, tankage proved to be slightly superior to either solvent or expeller soybean oil meal in rate and economy of gain when fed free-choice with corn and minerals.

Regardless of the method of feeding, expeller soybean oil meal required slightly less feed for 100 pounds gain than solvent soybean oil meal. Both meals were consumed in excessive amounts when fed singly as supplements in the free-choice rations. The solvent soybean oil meal produced faster gains than expeller soybean oil meal when fed either free-choice or in definite proportion with corn.

A second series of feeding trials were conducted at the Indiana Station in the fall of 1936. The experiment was designed to show the value of roasted soybeans and expeller process soybean oil meal in rations of brood sows

and growing pigs. The experiment began when the sows were bred and continued through the gestation and suckling period of the sows. Representative pigs from each lot were selected and fed through the early growing and fattening periods.

Tankage, soybean oil meal, and roasted soybeans made up the protein supplement to shelled corn in each of three lots. The farrowing and weaning records showed that the sows receiving the soybean oil meal during the gestation period farrowed the least number of pigs per litter. These results were just the opposite of results secured in a similar experiment conducted the previous fall (18). In both the 1935 and the 1936 feeding trials, the soybean oil meal-fed sows farrowed pigs heaviest in average birth weight, and weaned the largest number of pigs per litter. The pigs from the tankage-fed sows averaged more in weight at weaning than the pigs from the soybean oil meal-fed or soybean-fed sows.

During the early growth period, the pigs fed the roasted soybeans made faster daily gains and more economical gains than the lot receiving tankage or soybean oil meal. In economy of gain, tankage proved inferior to the soybean oil meal and roasted soybeans.

Throughout the fattening period, each lot of pigs had

the same ration, consisting of shelled corn, 60 per cent tankage, and mineral mixture. All feeds were self-fed free-choice while the pigs were on good alfalfa pasture.

The fattening records revealed that pigs receiving soybean oil meal during the early growing period, when fed a growing ration of corn, tankage, and mineral, made faster daily gains, more economical gains, on less total feed than pigs fed tankage or roasted soybeans during the growing period.

Studies at Ohio

After conducting several experiments with soybeans to determine their worth when fed in various ways and to secure information concerning methods of using them advantageously as a feed for pigs, the Ohio Station began a series of experiments to secure the same information for the soybean oil meal (17).

Results of two previous experiments (1919 and 1922) with soybean oil meals for pigs on rape pasture as a supplement for corn, showed such wide variations that later experiments (1930) were started. The purpose of the experiments conducted in 1930 was to determine if the method of processing affected the value of soybean oil meal as a supplemental feed for pigs.

Pigs averaging 49 pounds were selected and fed in six lots from December 11, 1929 to May 27, 1930. The pigs were on dry lot and received the following feeds.

Lot 1. Corn, ground soybeans, and minerals.

Lot 2. Corn, solvent soybean oil meal, and minerals.

Lot 3. Corn, hydraulic soybean oil meal, and minerals.

Lot 4. Corn, raw-tasting expeller soybean oil meal, and minerals.

Lot 5. Corn, nut-like expeller soybean oil meal, and minerals.

Lot 6. Corn, tankage, and minerals.

In order to compare the methods of feeding the meals, two methods of feeding were used. In one, the corn, protein supplement, and minerals were self-fed separately. In another method of feeding, the feeds were mixed and hand-fed. Several pigs, receiving their feed self-fed separately developed symptoms of rickets; while no such condition developed among the hand-fed pigs. The pigs receiving their feed self-fed separately made faster gains, but failed to consume minerals in amounts sufficient to prevent the lame and crampy condition.

The average of three tests showed the nut-like expeller meal, the hydraulic meal, the solvent meal, and the raw-tasting expeller meal ranked in the order named when rate

of growth and economy of growth are considered. The raw-tasting expeller and the solvent meals proved to be unsatisfactory supplements. The nut-like expeller meal compared favorably with tankage in every phase of the experiment; being superior to tankage when cost of feed per 100 pounds of gain is considered.

The results of 10 experiments in which expeller soybean oil meal was compared with tankage as supplements to corn for pigs in dry lots showed the soybean oil meal to be superior to tankage in every respect except rate of gain. The differences were small, but significant.

One experiment was conducted at the Ohio Station in which soybean oil meal was compared with ground soybeans and with tankage as a protein supplement to corn for pigs on forage. This experiment showed soybean oil meal produced gains 16 per cent faster than ground soybeans and 5 per cent faster than tankage. The soybean oil meal-fed pigs reached market weight (200 lbs.) 16 days earlier than the ground soybean-fed pigs, and 5 days earlier than those receiving tankage.

COMPILATION AND INTERPRETATION OF RESULTS SECURED AT
THE KANSAS STATION FROM FEEDING SOYBEAN OIL MEAL
AS A PROTEIN SUPPLEMENT IN SWINE RATIONS

A series of swine feeding investigations were conducted by the Kansas Agricultural Experiment Station with the object of determining the comparative value of soybean oil meal and various other protein supplements and supplemental mixtures for pigs self-fed corn on alfalfa pasture and in dry lots. These investigations were started in the winter of 1936 and are still in progress.

The feeds studied, in addition to soybean oil meal, as protein supplements were tankage, fish meal, soybeans, peanut meal, and various protein feed mixtures.

The results of those investigations in which soybean oil meal or soybean oil meal plus minerals was fed on a comparative basis with one or more of the above protein supplements are reviewed in the discussion which follows.

Investigations in 1937

In the summer of 1937 (June 22 to September 27) a feeding trial was carried out to determine the comparative value of tankage, soybean oil meal, mixtures of equal parts of soybean oil meal and tankage, and soybean oil meal plus

minerals as protein supplements for pigs self-fed corn on alfalfa pasture (3).

The pigs were divided into four separate lots of 8, 9, or 10 pigs each. Each feed in each lot was self-fed free-choice. Expeller process soybean oil meal was used. Where a mineral mixture was fed in conjunction with the soybean oil meal, the mixture consisted of 5 parts steamed bone meal, 5 parts ground limestone, and 1 part common salt.

The pigs averaged 65.57 pounds at the start of the experiment and were continued on the feed for 97 days. Observations made at the conclusion of this investigation revealed the following facts.

1. As a protein supplement for fattening pigs on alfalfa pasture, tankage proved superior to soybean oil meal, soybean oil meal plus minerals, or equal parts of tankage and soybean oil meal, when rate of gain is considered.

2. For economy of gain, soybean oil meal proved inferior to soybean oil meal plus minerals, tankage, and soybean oil meal and tankage in the order named.

3. Tankage, when compared with soybean oil meal without minerals as a protein supplement for pigs on alfalfa pasture, produced daily gains almost two times as rapidly. This showed soybean oil meal without minerals to be an inefficient protein supplement from the standpoint of rate as

well as economy of gain.

4. Soybean oil meal plus minerals compared favorably with tankage in rate of gain and proved to be better than tankage when economy of gain was considered.

5. The feed cost per 100 pounds of gain for all supplements was considerably higher than average. The cost per 100 pounds of gain were \$8.28, \$8.70, \$8.90, and \$10.95 for equal parts of tankage and soybean oil meal, soybean oil meal plus minerals, tankage, and soybean oil meal without minerals, respectively. (Shelled corn was charged at \$1.40 per bushel; tankage, \$50.00 per ton; soybean oil meal, \$37.00 per ton).

Investigations in 1937-38

A 116-day swine feeding trial was conducted at the Kansas Station during the winter of 1937-1938 (December 8, 1937 to April 2, 1938) (4). The purpose of this investigation was to secure additional information relative to the comparative value of tankage, whole soybeans, expeller process soybean oil meal, solvent process soybean oil meal, and soybean oil meal plus minerals as protein supplements for pigs self-fed corn and alfalfa hay in the dry lot.

The pigs averaged about 60 pounds at the beginning of the investigation and were divided into five lots of seven

or eight pigs each. The feed in each lot was self-fed free-choice. The mineral mixture was made up of 5 parts steamed bone meal, 5 parts ground limestone, and 1 part common salt.

From the results obtained, the following observations were made.

1. Solvent soybean oil meal plus minerals and expeller soybean oil meal plus minerals gave almost identical results where rates of gain and economy of gain are considered.

2. Both expeller soybean oil meal plus minerals and solvent soybean oil meal plus minerals proved superior to tankage, whole soybeans, and soybean oil meal without minerals, in the order named, when economy or rate of gains were considered.

3. Soybean oil meal without minerals was an inefficient protein supplement for pigs self-fed corn and alfalfa hay in dry lot.

4. Seventy-five per cent of the carcasses of the pigs which received whole soybeans were graded soft upon slaughter at the end of the experiment. This showed whole soybeans to be unsatisfactory as the sole protein supplement for fattening pigs.

5. The pigs fed soybean oil meal plus minerals ate less corn but considerably more protein than the tankage-

fed pigs for each 100 pounds of gain.

6. With shelled corn charged at \$.70 per bushel; tankage at \$50.00 per ton; whole soybeans at \$.80 per bushel; soybean oil meal at \$32.00 per ton; and alfalfa hay as \$13.00 per ton, the feed cost per 100 pounds gain ranged from \$5.24 for the lowest (expeller soybean oil meal plus minerals) to \$6.72 for the highest (soybean oil meal without minerals).

Swine Feeding Investigations in 1938

During the summer of 1938 (June 3 to September 23) a feeding experiment similar to the one conducted in the winter of 1937-1938 and described above was carried out at the Kansas Station. The 1938 experiment differed from the above experiment in that the pigs were on alfalfa pasture instead of in dry lots; otherwise the feeds and minerals used and the methods of feeding were identical. The pigs in the 1938 experiment were about 10 pounds heavier than those in the previous one.

Observations as to the comparative value of tankage, whole soybeans, expeller soybean oil meal plus minerals, solvent soybean oil meal plus minerals, and solvent soybean oil meal without minerals as protein supplements for pigs self-fed corn on alfalfa pasture were.

1. When rate of gain or economy of gain is considered, solvent soybean oil meal plus minerals proved superior to the other supplements for fattening pigs on alfalfa pasture.

2. Tankage and expeller soybean oil meal plus minerals were practically identical in respect to rate of gain and to feed cost per 100 pounds of gain. Both proved satisfactory as to rate and economy of gain.

3. Soybean oil meal without minerals was an inefficient protein supplement for fattening pigs on alfalfa pasture.

4. The pigs fed soybean oil meals plus minerals consumed less corn but three to four times as much protein supplement per 100 pounds of gain as did the tankage-fed pigs.

5. Upon slaughter of three of the pigs from the lot fed whole soybeans, each carcass graded soft. Therefore, whole soybeans were considered unsatisfactory as a protein supplement for fattening pigs.

Investigations in 1939

The swine feeding investigations conducted in the summer of 1939 (June 13 to September 30) by the Kansas Station were designed to show the comparative value of tankage,

fish meal, soybean oil meal, and mixtures of these feeds as protein supplements for pigs self-fed corn on alfalfa pasture.

The pigs averaged 69.72 pounds at the start of the experiment and were divided into six lots of nine pigs per lot. Each lot received shelled corn self-fed free-choice. In addition, the various lots received supplemental feeds as follows.

Lot 1. Tankage.

Lot 2. Fish meal.

Lot 3. Expeller soybean oil meal plus minerals.

Lot 4. Soybean oil meal, 1 part; tankage, 2 parts.

Lot 5. Soybean oil meal, 5 parts; tankage, 2 parts;
fish meal, 2 parts; cottonseed meal, 1 part.

Lot 6. Soybean oil meal, 5 parts; tankage, 4 parts;
cottonseed meal, 1 part.

The protein supplements and corn were self-fed free-choice. The protein content of the fish meal and soybean oil meal was 67 per cent and 41 per cent respectively. A mineral mixture consisting of 5 parts steamed bone meal, 5 parts ground limestone, and 1 part common salt was self-fed as a mixture to the pigs receiving the soybean oil meal (lot 3).

There was no significant difference between the rate

of gain in any of the lots.

The economy of gains was satisfactory for all supplemental feeds used.

Swine Feeding Investigations in 1940

The swine feeding experiments conducted at the Kansas Station the past winter (Dec. 21, 1939 to April 19, 1940) were carried out for the purpose of comparing the value of certain protein feed mixtures as supplements to shelled corn for fattening fall pigs in the dry lot.

The pigs were divided into five lots of eight pigs per lot. The average weight per pig at the beginning of the feeding trial was 72.11 pounds. Shelled corn and a mineral mixture were self-free free-choice in each lot. In addition to the shelled corn, the different lots were self-fed the following supplemental mixtures for 120 days.

Lot 1. Tankage; alfalfa hay.

Lot 2. Tankage, 2 parts; soybean oil meal, 1 part;
alfalfa meal, 1 part.

Lot 3. Soybean oil meal, 4 parts; tankage, 2 parts;
fish meal, 2 parts; cottonseed meal, 1 part;
alfalfa meal, 1 part.

Lot 4. Soybean oil meal, 5 parts; tankage, 2 parts;
fish meal, 2 parts; alfalfa meal, 1 part.

Lot 5. Soybean oil meal, 5 parts; tankage, 4 parts;
alfalfa meal, 1 part.

Following are the results obtained.

1. Tankage and alfalfa hay were inferior to all the protein mixtures when rate of gain and economy of gain were considered.

2. The pigs which received the more complex protein mixture (lot 3) made faster and more economical gains than the pigs which received any of the other supplemental mixtures. This showed a mixture of proteins from several sources to have a greater supplementing value to corn than a single protein or a more limited mixture.

3. The tankage-fed pigs (lot 1) required the least amount of protein and the largest amount of corn for each 100 pounds of gain.

4. The pigs fed the more complex protein mixture (lot 3) required the least amount of corn and the largest amount of protein for each 100 pounds of gain.

5. Satisfactory results were obtained in rate of gain and economy of gain from each of the protein mixtures.

Summarization of Results Secured at the Kansas Station from Feeding Soybean Oil Meal in Swine Rations

Several swine feeding investigations have been conducted at the Kansas Station to determine the relative

value of tankage, expeller process soybean oil meal plus minerals, solvent process soybean oil meal plus minerals, soybean oil meal without minerals, and whole soybeans. These investigations have been conducted under two sets of feeding conditions; i.e., with fattening pigs in dry lot and with fattening pigs on alfalfa pasture.

Pigs fed in a dry lot. In Table 5 are summarized the results obtained from feeding these supplements in dry lot. Complete data were available for one experiment under dry lot conditions.

Table 5. Tankage versus soybean oil meal, soybean oil meal plus minerals and whole soybeans as protein supplements for pigs self-fed corn in the dry lot (winter, 1937-38).

Ration	Shelled corn, alfalfa hay (self-fed)					
	: Soybean	: Soybean	: Soybean	: Soybean	: Soybean	: Soybean
	: oil meal	: oil meal	: oil meal	: oil meal	: oil meal	: oil meal
	: (expeller:	: (solvent	: Soybean	: Soybean	: Soybean	: Soybean
	: process)	: process)	: oil meal	: oil meal	: oil meal	: oil meal
	: age	: plus min-	: plus	: without	: soy-	: soy-
	: (Self-erals*	: minerals*	: minerals	: minerals	: minerals	: minerals
	: fed)	: (Self-fed)	: (Self-fed)	: (Self-fed)	: (Self-fed)	: (Self-fed)
No. pigs per lot:	7	8	8	7	8	8
Lot No.	1	2	3	4	5	6
	: Pounds	: Pounds	: Pounds	: Pounds	: Pounds	: Pounds
Av. initial wt.	: 60.38	: 59.17	: 59.42	: 61.68	: 58.79	: 58.79
Av. final wt.	: 226.90	: 235.08	: 232.92	: 182.57	: 186.50	: 186.50
Av. total gain	: 166.52	: 175.91	: 173.50	: 120.71	: 126.71	: 126.71
Av. daily gain	: 1.44	: 1.52	: 1.50	: 1.04	: 1.09	: 1.09
Av. daily ration:	:	:	:	:	:	:
Shelled corn	: 5.12	: 4.84	: 4.96	: 4.11	: 3.78	: 3.78
Tankage	: .54	:	:	:	:	:
Whole soybeans:	:	:	:	:	:	: .83
Ex.proc. soy-	:	:	:	:	:	:
bean oil meal	:	: 1.08	:	:	:	:
Sol.proc. soy-	:	:	:	:	:	:
bean oil meal:	:	:	: 1.03	: 1.01	:	:
Alfalfa hay	: .46	: .26	: .14	: .18	:	: .46
Minerals	:	: .03	: .04	:	:	:
Feed per 100 lbs. gain	:	:	:	:	:	:
Shelled corn	: 356.63	: 319.27	: 331.40	: 404.63	: 345.67	: 345.67
Tankage	: 37.58	:	:	:	:	:
Whole soybeans:	:	:	:	:	:	: 75.87
Ex.proc. soy-	:	:	:	:	:	:
bean oil meal:	:	: 70.99	:	:	:	:
Sol.proc. soy-	:	:	:	:	:	:
bean oil meal:	:	:	: 68.81	: 96.21	:	:
Alfalfa hay	: 32.17	: 16.84	: 9.08	: 17.75	: 41.83	: 41.83
Minerals	:	: 2.13	: 2.67	:	:	:

*Mineral mixture: 5 parts steamed bone meal, 5 parts ground limestone, and 1 part common salt.

Conclusions based upon this one experiment as to the comparative value of tankage, soybean oil meals plus minerals, soybean oil meal without minerals, and whole soybeans as protein supplements for fattening pigs self-fed corn and alfalfa hay in the dry lot are here given.

1. Expeller process soybean oil meal plus minerals proved to be slightly superior to solvent process soybean oil meal plus minerals in rate and economy of gains. The differences, however, were not significant.

2. Compared with soybean oil meals plus minerals, tankage was not as efficient from the standpoint of rate and economy of gains.

3. Soybean oil meal without minerals was inefficient as a protein supplement for fattening pigs in dry lot.

4. Whole soybeans were unsatisfactory as the sole protein supplement for fattening pigs from the standpoint of daily gain and economy of gain when compared to soybean oil meal with minerals. They also produced soft pork.

5. The tankage-fed pigs required more corn and less protein supplement than the pigs which received either expeller or solvent soybean oil meal plus minerals.

Pigs fed on pasture. Data obtained from three feeding investigations in which tankage, expeller soybean oil meal plus minerals, solvent soybean oil meal plus minerals, soy-

bean oil meal without minerals, and whole soybeans were studied as to their relative value as protein supplements for fattening pigs self-fed corn on alfalfa pasture, are averaged and presented in Table 6.

The results obtained at the Kansas Station when soybean oil meal and minerals were fed on a comparative basis with tankage, whole soybeans, and soybean oil meal without minerals as a protein supplement for fattening pigs self-fed corn in dry lot or on alfalfa pasture revealed the following facts.

1. When rate and economy of gain are considered, tankage proved to be superior to expeller process and solvent process soybean oil meals plus minerals for fattening pigs on alfalfa pasture, while expeller soybean oil meal and minerals proved to be superior to the tankage and solvent soybean oil meal plus minerals for fattening pigs in dry lot.

2. Soybean oil meals without minerals are inefficient as a protein supplement for fattening pigs.

3. Because whole soybeans produce less gain and soft pork, they are unsatisfactory as the sole protein supplement for fattening pigs.

5. The pigs fed expeller process soybean oil meal and minerals required slightly less corn and more protein than

Table 6. Comparative value of tankage, expeller soybean oil meal plus minerals, solvent soybean oil meal plus minerals, soybean oil meal without minerals, and whole soybeans as protein supplements for fattening pigs self-fed corn on alfalfa pasture. (Average of three trials in the summer of 1937, 1938 and 1939) (5).

	Shelled corn, alfalfa pasture				
	: Soybean	: Soybean	:	:	:
	: oil meal:	: oil meal:	: Soybean	:	:
	: (expeller:	: (Solvent:	: oil meal:	: Whole	:
	: Tank-	: process):	: process):	: (Solvent:	: soy-
	: age	: minerals*	: minerals*	: process):	: beans
	: (Self-	: (Self-	: (Self-	: (Self-	: (Self-
Ration	: fed	: fed	: fed)	: fed)	: fed)
No. pigs per lot	: 9	: 8	: 9	: 10	: 10
Lot No.	: 1	: 2	: 3	: 4	: 5
	: Pounds	: Pounds	: Pounds	: Pounds	: Pounds
Av. initial wt.	: 67.62	: 68.12	: 69.00	: 65.73	: 67.53
Av. final wt.	: 223.68	: 212.31	: 229.52	: 153.16	: 161.30
Av. total gain	: 154.04	: 144.49	: 160.52	: 87.43	: 93.77
Av. daily gain	: 1.48	: 1.36	: 1.43	: .82	: .84
Av. daily ration	:	:	:	:	:
Shelled corn	: 4.85	: 3.82	: 4.31	: 3.30	: 3.54
Tankage	: .28	:	:	:	:
Whole soybeans	:	:	:	:	: .18
Ex.proc. soy-	:	:	:	:	:
bean oil meal:	:	: 1.07	:	:	:
Sol.proc. soy-	:	:	:	:	:
bean oil meal:	:	:	: .66	: .55	:
Minerals	:	: .04	: .03	:	:
Feed per 100 lbs.:	:	:	:	:	:
gain	:	:	:	:	:
Shelled corn	: 338.77	: 282.74	: 300.55	: 394.37	: 422.52
Tankage	: 19.53	:	:	:	:
Whole soybeans	:	:	:	:	: 21.76
Ex.proc. soy-	:	:	:	:	:
bean oil meal:	:	: 77.42	:	:	:
Sol.proc. soy-	:	:	:	:	:
bean oil meal:	:	:	: 46.10	: 66.56	:
Minerals	:	: 2.85	: 2.18	:	:

*Mineral mixture: 5 parts steamed bone meal, 5 parts ground limestone, 1 part common salt.

the tankage-fed and solvent soybean oil meal-fed pigs for each 100 pounds of gain.

CONCLUSION

A review and study of all the data available indicate that soybean oil meal is a satisfactory protein supplement in swine feeding rations if and when fortified with a mineral mixture.

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