



LIBRARY
OF THE
UNIVERSITY
OF ILLINOIS

630.7
Il6b
no. 433-444
cop. 2

AGRICULTURE



Value and Use of Oats in the Rations of Growing-Fattening Swine

By W. E. CARROLL
W. P. GARRIGUS
G. E. HUNT
R. A. SMITH



UNIVERSITY OF ILLINOIS
AGRICULTURAL EXPERIMENT STATION

Bulletin 436

CONTENTS

	PAGE
REVIEW OF EARLY LITERATURE.....	115
DESCRIPTION OF ILLINOIS EXPERIMENTS.....	118
Purpose and Plan.....	118
Statistical Treatment of the Data.....	120
VALUE OF OATS IN RATION DECLINED AS PROPOR-	
TION INCREASED	120
Oats Not More Than One-Third of Ration.....	121
Oats Up To One-Half of Ration.....	121
Rations One-Third and One-Half Oats.....	123
General Analysis of All Three Tests.....	125
SAVING OF PROTEIN SUPPLEMENT IN OATS	
RATIONS.....	126
GAINS WERE SLOW ON OATS AND TANKAGE.....	127
GRINDING OATS INCREASED THEIR EFFECTIVE-	
NESS.....	129
Six Tests Made of Value of Grinding Oats.....	129
General Analysis of Grinding Tests.....	136
Tests at Other Stations on Grinding Oats.....	137
COARSE OR FINE GRINDING OF OATS.....	139
VALUE OF OAT KERNELS IN SWINE RATIONS.....	141
Feeding Tests With Steel-Cut Oats.....	143
Feeding Tests With Hulled Oats.....	145
Feeding Tests With Hull-less Oats.....	145
Further Tests With Hulled Oats.....	149
Stiffness in Pigs Fed Hulled-Oats Rations.....	156
General Analysis of Data on Value of Oat Kernels.....	162
Tests With Oat Kernels at Other Stations.....	165
GENERAL SUMMARY AND CONCLUSIONS.....	166
LITERATURE CITED.....	168
APPENDIX.....	169
LIST OF TABLES.....	171

Value and Use of Oats in the Rations Of Growing-Fattening Swine

By W. E. CARROLL, W. P. GARRIGUS, G. E. HUNT, and R. A. SMITH*

AS A FEED FOR SWINE oats had little interest for corn-belt farmers so long as work animals on farms and in cities absorbed the supply commonly grown in corn-belt rotations. But with the sharp falling off of numbers of horses and mules that occurred in the United States after about 1920, and the continued high acreage of oats planted, prices for oats slumped markedly in relation to other feed grains. In order to explore the possibilities of extending the use of oats on farms, and thereby improving their market position, a ten-year study of the value of oats in swine rations was undertaken by the Illinois Station in 1926. The practical questions involved were: (1) at what price differential between corn and oats does the feeding of oats to swine become profitable; (2) to what extent may oats be substituted for corn in the rations of such pigs without reducing the efficiency of the ration; and (3) by what method of preparation may oats be made most palatable and useful to swine.

Altho farmers had of course fed oats to hogs long before these experiments were undertaken, very little definite information was obtainable on the questions stated above. Only four tests in which oats had been fed experimentally to fattening pigs had been reported by the experiment stations of the country.

REVIEW OF EARLY LITERATURE

Early Wisconsin tests. The results of a study of the value of grinding oats to be fed to fattening pigs were reported by Henry^{7*} in 1889. Whole and ground oats were fed with ground corn in the ratios of 2 parts corn to 1 part oats, and 1 part corn to 2 parts oats, to twelve pigs that averaged 74 pounds in weight and were from 108 to 125 days old at the beginning of the test.

The pigs were divided into four lots of three each and fed for four 30-day periods. The rations were rotated among the groups during a transition period of one week between each two test periods. The study

*W. E. CARROLL, Chief in Swine Husbandry, W. P. GARRIGUS, G. E. HUNT, and R. A. SMITH, all formerly Assistants in Swine Husbandry. The authors are indebted to the statistical staff of the Department of Animal Husbandry for the statistical treatment of the data.

*These numbers refer to literature citations on page 168.

consisted, therefore, of three repetitions of the first 30-day test, except that the initial weight and the previous treatment of the pigs varied with each repetition. The report made gives no information on the quality of the oats fed nor the degree of fineness to which they were ground. Inasmuch as this experiment was made before the introduction of the hammer mill, it is safe to assume that the oats were coarse ground.

A recalculation and regrouping of the results of the foregoing tests show them to be rather uniform and consistent from period to period. Actual values varied somewhat, but grinding the oats always increased both the rate and the economy of gain, whether the oats were fed with corn in the ratio of 2 parts corn to 1 part oats or 1 part corn to 2 parts oats. The higher proportion of oats likewise consistently reduced the rate and economy of gain in all the periods.

The results obtained in the four periods are grouped as averages in Table 1 on the basis of the rations fed. From the increased amount of whole oats consumed by the pigs that were fed the high-oats ration (second column) and the lesser amount of corn for each 100 pounds of gain made, compared with the respective consumption of these feeds by the pigs that received less oats (first column), it is possible to compute that each 100 pounds increase in consumption of whole oats resulted in a saving of 66 pounds of corn. A similar computation of the data derived from feeding ground oats (third and fourth columns) shows that the consumption of 100 pounds of additional ground oats (fourth column) saved 82 pounds of corn.

TABLE 1.—COMPARISON OF WHOLE AND GROUND OATS IN THE RATIOMS OF SWINE:
EARLY WISCONSIN TESTS^a
(Averages of four 30-day periods, 3 pigs to the lot)

	Data on lots fed corn and whole oats		Data on lots fed corn and ground oats	
	2:1	1:2	2:1	1:2
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight.....	114	117	114	113
Average final weight.....	138	137	152	144
Average daily gain.....	.82	.68	1.27	1.03
Average daily ration.....	4.05	3.86	5.11	4.42
Feed for 100 pounds gain				
Corn.....	328	188	268	143
Oats.....	164	376	134	286
Total.....	492	564	402	429

^aComputed from a report by W. A. Henry, in Wis. Agr. Exp. Sta. Ann. Rpt. 6 (1889), pp. 20-23.

Grinding 100 pounds of oats to be fed at the lower ratio (2 parts corn to 1 part oats) apparently saved 45 pounds of corn and 22 pounds of oats, on the average; whereas when the ratio was 1 part corn to 2 parts oats only 16 pounds of corn and 31 pounds of oats apparently were saved. Even the smaller amount is a substantial saving and amply justifies Dean Henry's recommendation that "for such hogs, when fed for rapid gains, the oats should always be ground, and the quantity limited in the ration to something like one-third of the total amount [of feed]."

In one section of the data on this test there is a very definite indication that larger pigs utilize oats to better advantage than do smaller pigs.

Ohio tests. The Ohio Agricultural Experiment Station^{2*} reported in 1914 the results of two trials of feeding oats to pigs. In the first test a mixture of ground corn and tankage was compared with a mixture of ground oats and tankage. The ratio of grain to tankage was 9:1 in each case. Five pigs were started on each ration, and the test was continued for 126 days. At the end of this time the weights of the three surviving corn-fed pigs averaged 269 pounds, while the four surviving oats-fed pigs averaged only 196 pounds. In this test 100 pounds of ground oats saved approximately 80 pounds of corn.

In the second test different proportions of oats were fed for 84 days to pigs starting at 150 pounds. Lot 1 received a mixture of 9 parts corn and 1 part tankage; Lot 2, 6 parts corn, 3 parts oats and 1 part tankage; Lot 3, 3 parts corn, 6 parts oats and 1 part tankage; and Lot 4, 9 parts oats and 1 part tankage. The average daily gains made on the respective rations were 1.75, 1.57, 1.49 and .99 pounds. On a basis of feed eaten in making 100 pounds of gain in this test, 100 pounds of ground oats saved approximately 73 to 85 pounds of other feed. The smaller saving was realized when oats completely replaced corn.

The oats fed in these two tests contained on the average 11.4 percent of fiber. During the first three weeks of the second test the oats fed were reported to weigh 31 pounds, and during the remainder of that test, 28 pounds a bushel.

These results suggest that oats are less valuable per pound than corn for fattening pigs, and that increasing the proportions of oats in the ration decreases the rate and economy of gain.

Oklahoma tests. Two short tests on feeding oats to pigs were reported by the Oklahoma Station in 1923.^{20*} In both tests a ration of oats and tankage was compared with a ration of corn and tankage. The pigs weighed 140 to 160 pounds at the start. According to the meager

results of these tests that have been published, 100 pounds of oats supplemented by tankage replaced about 60 pounds of corn when the large difference in rate of gain is disregarded.

DESCRIPTION OF ILLINOIS EXPERIMENTS

Purpose and Plan

On the basis of the data from the four tests reviewed above and unpublished data from three tests made at the Illinois Station in 1917-18,^a additional work was undertaken at the Illinois Station in 1926 in an attempt to determine more accurately the value of oats fed in different forms and proportions in the rations of swine. Seventeen different feeding trials in all were conducted in which 1,290 growing-fattening pigs were fed. Oats were also fed experimentally to brood sows during the course of the experiments, but the results are not reported in this bulletin.

Uniform methods of investigations were used thruout the study, except for certain minor differences between the three early tests and those that were conducted after 1925. All the feeding was done in drylot. Twenty pigs were fed in each lot except in two of the early tests using lots of 8 and 12 pigs respectively, two lots in the 1926 test using 18 pigs each, and the lots in the 1934-35 test in which only 10 pigs each were used. The initial weights of the pigs in the different lots averaged, by the lot, from 51 to 77 pounds.

In making up the lots of pigs for each test, care was taken to equalize the lots in weight, sex, breed, and as nearly as possible in general thrift and probable outcome. Except for three emergencies (noted in the discussion of results) each group of pigs was continued on the experimental ration until the week end that the average weight of the pigs comprizing it most nearly approximated 200 pounds. Inasmuch as final weight itself affects the average daily gain and the amount of feed consumed per unit of gain, uniformity of final weight was considered essential for making comparisons between the experimental groups.

Weights of the individual pigs were taken on three consecutive days at the beginning and at the close of each test and on one day at biweekly intervals during the test. The feed fed to each group was carefully weighed.

Water and salt, and in some of the tests a simple mineral mixture, were available to the pigs at all times. When bedding was needed,

^aSee pages 127 to 128 of this bulletin for a summary of these tests.

straw was used. Except for the ration differences being studied, all conditions, including the management of the animals, size of pens and lots, shelter, and feedlot equipment, were maintained as uniform as possible for the various lots within any one test; and even from test to test the conditions were very similar except for the necessary difference in handling the pigs in summer and in winter.

The corn that was fed thruout the study was yellow and usually of good quality, grading No. 2, 3, or 4. The oats were, in general, of good quality, varied in weight per bushel from year to year from 27 to 34 pounds, and the percentage of kernel in the oats, as determined by hand-shelled samples, varied from 66 to 75 percent. The tankage fed was of standard grade guaranteed to contain 60 percent protein. The oil meals and alfalfa meal used were likewise of standard commercial grades.

Not all the feeds that were used were submitted to chemical analysis. In some cases the feed mixtures but not the individual feeds were analyzed. The available analytical data on the composition of individual feeds are assembled in Tables 26 and 27, Appendix, suitable reference being made to the test in which each feed was fed.

The method used in these tests to determine the value of the oats fed was to replace with the oats that were to be tested a portion or all of the corn in a well-balanced ration, and to compare the rate of gain and the feed consumption of the pigs fed the modified rations with the rate and economy of gain of similar pigs fed the standard ration. The amount of other feeds replaced by a given amount of oats per unit of gain indicates the value of the oats in terms of the other feeds.

In feeding investigations which involve the determination of the value of one feed in terms of another, as was the case in this study, it is highly desirable that the rations under comparison have about the same nutritive values so as to induce approximately equal rates of gain in the experimental animals. Otherwise there is no means of knowing whether an observed difference in feed economy is due to the experimentally imposed differences in the rations or merely to a difference in the *rate* of increase in weight, or even to both in unknown proportion, since the rate at which body gain is made is a factor in the "overall" feed economy of that gain.

For the most part the rations that were compared in any one test reported in this **bulletin** proved to be substantially equal in their capacities to induce gain in the experimental animals, for there was a general lack of statistical significance in the differences in mean gains among groups of pigs within a given test.

Statistical Treatment of the Data

Since the pigs were weighed individually, it was possible to determine statistically the significance of differences in average daily gain among lots by computing the probable error of the mean daily gain for each lot and the probable error of the difference between means.^a When a difference is three times its probable error the odds are approximately 21 to 1 that the difference is due, not to chance, but to the imposed experimental conditions. Thruout this study, therefore, when the gains made by two lots of pigs differed by an amount three or more times its probable error, the difference is regarded as being significant and is believed to be due to differences in the rations fed. Differences smaller than three times their probable errors are not considered significant.

Unfortunately, when animals are fed in groups there is no method of determining for an individual experiment when differences in feed eaten for a unit of gain are, and when they are not, significant statistically.

VALUE OF OATS IN RATION DECLINED AS PROPORTION INCREASED

In view of the relatively small capacity of the digestive tract of pigs on the one hand and the high fiber content of oats on the other, it is not surprising that the early tests indicated that large amounts of oats in the ration of fattening pigs are a handicap to rapid and economical gain. The extent to which oats may profitably replace corn depends of course to a large extent on the current prices of the two grains. An understanding, however, of the manner in which an increase in the proportion of oats in the ration affects the rate of gain and the total feed requirements is essential as a basis for judging how extensively oats may be fed with profit under different price relations.

Inasmuch as the published reports of feeding tests gave at best

^aThe probable error of a mean was obtained by dividing the standard deviation by the square root of the number of animals in the lot and multiplying by .6745, in accordance with the formula, $PE_m = .6745 \frac{\sigma}{\sqrt{n}}$.

The probable error of the difference between two means was obtained by taking the square root of the sum of the squares of the probable errors of the two means, thus, $PE_d = \sqrt{(PE_1)^2 + (PE_2)^2}$.

The formula used to derive the standard deviation was, $\sigma = \sqrt{\frac{\sum d^2}{n-1}}$, in which d equals the deviation of the gain of the individual animals from the mean gain of the group and n equals the number of animals per lot.

only meager information on this particular question, more detailed investigations were begun at the Illinois Station in 1927. In all, three tests of the effectiveness of different proportions of oats in rations were made, the results of which indicated that oats may replace a considerable part of the corn without greatly affecting the rate of gain by the pigs. The feed consumed for each unit of gain made was, however, almost always somewhat higher when oats were used as a part of the ration than when only corn and supplement were fed.

Oats Not More Than One-Third of Ration

The first experiment on the effectiveness of different proportions of oats in the ration, conducted during the summer of 1927, included tests of both whole and ground oats. No decline in rate of gain that could be attributed to increasing the proportion either of whole or of ground oats up to one-third of the grain mixture occurred (Table 2). The differences in gain from lot to lot were not statistically significant. In all cases, however, somewhat more of the oats rations than of the check ration was eaten for each 100 pounds of gain made, but there is no way of determining whether these differences are statistically significant.

Complete chemical analyses of the feeds used in this test unfortunately were not made, and it was therefore impossible to know whether the rations differed in composition enough to explain the observed differences in response of the pigs. Altho the fiber content of the ration was necessarily increased with each increase in the proportion of oats, it is doubtful whether the fiber content of even the rations that contained most oats was high enough to interfere materially with the utilization of the ration.

Oats Up To One-Half of Ration

Further studies on the effectiveness of different proportions of oats were made during the summer of 1929, when three groups of pigs were fed rations that contained cracked corn and ground oats in the proportion of 3:1, 2:1, and 1:1, and a fourth group was fed no oats. Because the previous test indicated rather plainly that the lowest proportion of oats used in that test (1 part oats to 4 parts corn) did not retard gains, that ration was dropped from this second test and the 1:1 corn-oats ration added.

The results of the second test (Table 3) are in general agreement with the earlier results. Oats fed even to the extent of half the grain, Lot 4, did not slow up the gains. As in the previous test, however, somewhat more of the oats rations than of the check ration was eaten

TABLE 3.—PROPORTIONS OF GROUND OATS* IN THE RATIONS OF GROWING-FATTENING PIGS: SECOND TEST

(Test began July 13, 1929, with 20 pigs to the lot.^b The corn and corn-oats mixtures were self-fed free-choice with supplement)

	Lot 1 Cracked corn	Lot 2	Lot 3	Lot 4
		Cracked corn and fine-ground oats		
		3:1	2:1	1:1
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight ^c	66	65	67	67
Average final weight ^c	205	202	202	206
Average daily gain ^c	1.25	1.30	1.28	1.24
Average daily ration				
Cracked corn.....	4.76	3.82	3.47	2.41
Fine-ground oats.....		1.27	1.77	2.41
Supplement, ^d free-choice.....	.75	.66	.75	.68
Total.....	5.51	5.75	5.99	5.50
Feed for 100 pounds gain				
Cracked corn.....	387	301	271	202
Fine-ground oats.....		101	139	202
Supplement ^d	61	52	58	57
Total.....	448	454	468	461
Composition of ration ^e	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>
Dry substance.....	86.89	87.59	87.90	88.40
Protein.....	12.44	12.41	12.95	13.37
N-free extract.....	62.63	61.25	59.92	58.34
Fiber.....	4.56	6.37	7.08	8.32
Ether extract.....	4.18	4.25	4.34	4.44
Ash.....	3.08	3.31	3.61	3.93

*The oats fed in this test weighed 31 pounds to the bushel and contained 29 percent of hull. The corn was largely No. 2, tho some No. 3 was fed.

^bTwo pigs in Lot 1, one in Lot 2, one in Lot 3, and two in Lot 4 became unthrifty and were removed.

^cFor the pigs that finished.

^dSupplement contained 2 parts tankage, 1 part linseed meal, and 1 part alfalfa meal.

^eComputed analyses shown in Tables 26 and 27, Appendix.

per pound of gain. These differences are in themselves probably too small to be significant. The fact that similar differences occurred in the earlier test indicates that the substitution of oats for a part of the corn reduces the efficiency of the ration.

These small differences in efficiency can be explained largely by differences in the fiber content of the rations fed. In fact, if allowance is made for the excess fiber carried by the rations fed Lots 2, 3, and 4, the total feed eaten for each 100 pounds of gain was very uniform. Apparently, therefore, the other small differences in the composition of the rations, shown in Table 3, had no influence on either the rate or the economy of gain.

Rations One-Third and One-Half Oats

Since it seemed evident from the two preceding tests that small proportions of oats in the ration would not retard the gain of pigs, the

third test made in 1930 included only rations in which corn and oats were mixed in the ratios of 2 parts corn to 1 part oats, and 1 part corn to 1 part oats. A slight change was made also in the plan of feeding.

In the two previous tests the oats and corn, mixed in the proportion in which they were to be tested, were fed free-choice with the protein supplement. But in the third test the protein supplement was mixed with the grain mixture in such amounts as would approximately equalize the total protein of the three rations to be tested, and these mixtures were then self-fed.

The ration that contained equal parts of corn and oats (Lot 3) was apparently somewhat less effective than either of the other rations (Table 4). The difference in rate of gain between Lot 3 and Lot 1 (the check) was 2.7 times its probable error, just short of statistical significance. The difference in feed consumed per unit of gain made by the pigs in these two lots, tho not amenable to statistical measurement for significance, does seem large enough to be of practical importance. The fiber content of the ration for Lot 3 was not enough higher than

TABLE 4.—PROPORTIONS OF GROUND OATS IN THE RATIONS OF GROWING-FATTENING PIGS: THIRD TEST

(Test began July 15, 1930, with 20 pigs to the lot. Rations^a were mixed and self-fed)

	Lot 1 Corn 80 lbs. Suppl. 20 lbs.	Lot 2 Corn 56 lbs. Oats 28 lbs. Suppl. 16 lbs.	Lot 3 Corn 43 lbs. Oats 43 lbs. Suppl. 14 lbs.
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight.....	73	73	72
Average final weight.....	201	201	200 ^b
Average daily gain.....	1.66	1.61	1.51 ^b
Average daily ration			
Cracked corn.....	5.14	3.42	2.80
Fine-ground oats.....	.....	1.70	2.80
Supplement ^c	1.29	.98	.91
Total.....	6.43	6.10	6.51
Feed for 100 pounds gain			
Cracked corn.....	310	213	189
Fine-ground oats.....	.....	106	189
Supplement ^c	78	61	62
Total.....	388	380	440
Composition of rations ^d	<i>percl.</i>	<i>percl.</i>	<i>percl.</i>
Dry substance.....	89.26	89.52	89.67
Protein.....	15.13	14.63	14.43
N-free extract.....	60.88	59.58	58.76
Fiber.....	4.29	6.07	7.04
Ether extract.....	4.62	4.90	5.06
Ash.....	4.34	4.34	4.38

^aThe oats fed in this test weighed 33 pounds to the bushel, and contained 29 percent of hulls. The corn was largely No. 2 grade, with a little of No. 3.

^bFor the 19 pigs that finished.

^cSupplement contained 2 parts tankage, 1 part linseed meal, and 1 part alfalfa meal.

^dComputed from analyses shown in Tables 26 and 27, Appendix.

that of the other rations to explain the greater amount of feed eaten for each unit of gain made by the pigs of this lot. Neither can this difference in total feed consumption be explained by other differences in the chemical composition of the rations.

The smaller proportion of oats in Lot 2 had no effect on rate or economy of gain altho this ration carried nearly 2 percent more fiber than the check ration.

The percentage of protein in all of these rations was high because the proportion of supplement was not reduced as the weight of the pigs increased, as was planned at the beginning of the test.

General Analysis of All Three Tests

When the data from comparable groups in the three experiments just described are averaged (Table 5), further emphasis is given to some of the points indicated in the individual tests, namely: (1) that until oats make up at least half the ration they do not retard the gain of pigs; (2) that the effect on gains even in the one-half proportion is not positively detrimental; and (3) that when oats are used to replace any part of the corn in a ration, there is an increase in the total amount of feed eaten per unit of gain made.

TABLE 5.—PROPORTIONS OF GROUND OATS IN THE RATIONS OF GROWING-FATTENING PIGS: SUMMARY OF THE THREE TESTS

(Averages of 4 comparisons involving 11 lots of 20 pigs each. Rations were self-fed, and were free-choice with supplement except in one test, Table 4)

	1927-1929			1929-1930*		
	Cracked corn	Cracked corn and ground oats—		Cracked corn	Cracked corn and ground oats—	
		3:1	2:1		2:1	1:1
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight.....	67	66	66	70	70	70
Average final weight.....	200	200	202	203	202	203
Average daily gain.....	1.24	1.29	1.28	1.46	1.44	1.38
Average daily ration						
Cracked corn.....	4.61	3.74	3.42	4.95	3.44	2.60
Fine-ground oats.....		1.24	1.73		1.74	2.60
Supplement.....	.78	.68	.68	1.02	.86	.80
Total.....	5.39	5.66	5.83	5.97	6.04	6.00
Feed for 100 pounds gain						
Cracked corn.....	374	294	270	348	243	195
Fine-ground oats.....		98	136		123	195
Supplement.....	63	53	54	70	60	60
Total.....	437	445	460	418	426	450
Feed saved by 100 pounds of oats.....		92	83		93	83

*The two sections of the table cannot be compared, for they involve different tests.

Each pound of oats became less effective in saving feed as the proportion of oats in the ration was increased, according to these averages. When, in comparison with the check lot (Table 5, first column), the proportion of oats was increased from one-fourth to one-third of the ration (second and third columns), the amount of feed replaced by each 100 pounds of oats decreased from 92 pounds to 83 pounds. A similar decrease occurred when in another group of tests the proportion of oats was increased from one-third to one-half of the grain mixture (fifth and sixth columns). Likewise when the oats rations are compared with each other this decrease in the effectiveness of the oats is noticeable. The pigs that were fed corn and oats in the ratio 3 parts corn to 1 part oats consumed 98 pounds of oats per hundredweight of gain made, while pigs in the same experiments that were fed a mixture of 2 parts corn to 1 part oats consumed 136 pounds of oats but somewhat less corn per hundredweight of gain. If the difference in amount of oats eaten (38 pounds) is compared with the difference in amounts of corn and supplement consumed (23 pounds), it is evident that for each 100 pounds of oats consumed over and above the lower level of oats feeding there was a saving of only 61 pounds of corn and supplement. A similar computation of the data in the second section of the table indicates a saving of only 67 pounds of corn and supplement for each 100 pounds of additional oats consumed by the pigs that received the high-oats ration over the amount fed the other pigs.

The significance of this progressive decline in the effectiveness of oats as the proportion of them in the ration increased is rather difficult to estimate, for in only one of the individual tests—that of 1930—did it appear in any pronounced degree. The relationship is not, however, inconsistent with the observation already made (page 121) that mixtures of corn and oats are somewhat less efficient in producing gain than is a ration based on corn alone. Nor is it inconsistent with the strikingly lower value of oats compared with corn when each is fed as the sole grain with supplement, as was done in the 1917 tests reported in Table 6.

SAVING OF PROTEIN SUPPLEMENT IN OATS RATIONS

A smaller amount of protein supplement is required to balance a ration from the standpoint of protein when oats are a part of the ration than when only corn and supplement are fed, because oats contain about 2.5 percent more protein per unit of weight than does corn. The additional protein supplied by 100 pounds of oats should thus

replace slightly more than 6 pounds of supplement containing 42 percent protein, such as was used in these tests. The actual saving of protein supplement, however, in the nine lots in which the supplement was fed free-choice, varied from 2 to 18 pounds per 100 pounds of oats fed (Tables 2, 3 and 4). The average saving was 9 pounds. There was a tendency for the amount of supplement saved by each unit of oats fed to decline somewhat as the proportion of oats in the ration increased.

The percentage of protein in the total ration was remarkably constant among the nine groups of pigs that had free access to the protein supplement in these particular experiments. The extreme variation between lots was only 1 percent and most of the percentages were within .5 percent of each other. Such small variations in the percentage of protein in the rations (at this level) do not affect the rate or economy of gain, according to later investigations at this Station.

GAINS WERE SLOW ON OATS AND TANKAGE

That oats are too bulky to be fed to fattening pigs to the exclusion of other grains when rapid gains are desired is well understood. The only test made at this Station involving this extreme comparison of corn and whole oats was conducted during the winter of 1917-18.^a Four lots of ten 93-pound pigs each were self-fed the following rations: Lot 1, shelled corn and tankage free-choice; Lot 2, whole oats and tankage free-choice; Lot 3, corn, whole oats, and tankage free-choice; and Lot 4, whole oats and tankage free-choice for 98 days followed for 28 days by shelled corn, whole oats, and tankage free-choice. The pigs of each lot were fed until their average weight reached 200 pounds.

The results of this test are summarized in Table 6. The pigs fed only whole oats and tankage gained only two-thirds as fast as those fed corn and tankage, and required 36 percent more total feed per hundredweight of gain. Oats-fed pigs required on an average 140 days to gain 103 pounds, while pigs on the corn ration gained on an average 110 pounds in only 98 days (Lots 1 and 2, Table 6). One hundred pounds of oats plus an excess of 15 pounds more tankage than was consumed by the corn-fed pigs replaced only 81 pounds of corn.

On the other hand, the gains of the pigs that were fed corn, oats, and tankage thruout the test (Lot 3) were fully equal to the gains

^aThis test was conducted under the direction of J. B. Rice, at that time Associate in Animal Husbandry.

TABLE 6.—WHOLE OATS AS A SUBSTITUTE FOR CORN IN THE RATIONS OF GROWING-FATTENING PIGS: SUMMARY OF WEIGHTS, GAINS, AND FEED CONSUMPTION*
(Test began Dec. 24, 1917, with 10 pigs to the lot. All feeds were fed free-choice)

	Lot 1 Corn and tankage	Lot 2 Whole oats and tankage	Lot 3 Corn, whole oats and tankage	Lot 4 Whole oats and tankage fol- lowed by corn, whole oats and tankage
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight.....	92	93	96	92
Average final weight.....	202	196	196	199
Average daily gain.....	1.12	.74	1.18	.85
Average daily ration				
Shelled corn.....	4.40	.....	3.78	1.04 ^b
Whole oats.....	.....	3.60	1.29	3.10 ^c
Tankage.....	.71	1.00	.56	.79
Total.....	5.11	4.60	5.63	4.93
Feed for 100 pounds gain				
Shelled corn.....	394	.....	320	122 ^b
Whole oats.....	.....	489	109	365 ^c
Tankage.....	64	136	47	93
Total.....	458	625	476	580

*This test was conducted under the direction of J. B. Rice, then Associate in Animal Husbandry.

^bFed only during last 28 days.

^cFed without corn during first 98 days.

produced by the corn-and-tankage ration. In this ration 100 pounds of oats replaced 64 pounds of corn and 16 pounds of tankage.

Tho the results of a single trial of this kind can hardly be considered to prove a point, they are in close enough agreement with the results of tests conducted more recently at other stations to warrant placing some confidence in them. In two tests reported by Robison^{13, 18*} pigs that were fed *whole oats* and supplement gained 69 percent as rapidly as, and ate 35 percent more total feed in making 100 pounds of gain than pigs that were fed corn and supplement.

In ten similar trials^{2, 7, 10, 11, 12, 13, 14, 15, 19, 20, 21*} in which the oats were ground and fed as the sole grain, the gains on oats rations were 74 percent as rapid as on corn rations, and the increased feed consumption per unit of gain over the corn-fed groups was 32 percent.

The results of these various tests of the effect of different proportions of oats in the rations of growing-fattening pigs suggest that to be fed profitably to such pigs, oats must be at least as cheap as corn per pound, and that for greatest efficiency the proportion of oats in the ration should not exceed possibly one-third or, at most, one-half the grain fed.

GRINDING OATS INCREASED THEIR EFFECTIVENESS

Grinding is the most common farm method of preparing oats for fattening pigs.

The value realized in practice from grinding depends somewhat upon the method of feeding the oats. Pigs eat ground oats, especially if fine ground, very much more freely than whole oats.^{1*} Consequently, when fine-ground oats are fed free-choice with corn and supplement, the pigs may eat so much of the oats as to reduce their rate of gain and increase correspondingly their feed requirements. This reduced efficiency of the ration results, of course, not from grinding the oats but from the greatly increased proportion of oats eaten (see discussion in preceding section).

Reference has already been made (page 115) to one early test at the Wisconsin Station^{7*} which showed that grinding oats increased the rate and economy of gain of fattening hogs.

During the winter of 1918 a comparison was made at the Illinois Station^a of whole oats and ground oats for feeding to fattening pigs. Twenty 54-pound pigs were fed to market weight on shelled corn, whole oats, and tankage, and the same number of similar pigs were given shelled corn, coarse-ground oats, and tankage. A check group was fed a ration of shelled corn and tankage. All feeds were offered free-choice. As would be expected under such conditions, relatively more ground oats than whole oats were consumed, tho the difference was not large (1 part ground oats to 8 parts corn, and approximately 1 part whole oats to 10 parts corn). Differences in rate and economy of gain were not significant, tho, contrary to most such work, 100 pounds of whole oats replaced more feed than did 100 pounds of ground oats. This unusual condition is no doubt to be explained by the inherent variations in such work and the very small amount of oats consumed, rather than by actual ration differences.

Inasmuch as the data from this test were too limited to be conclusive, additional tests on the value of grinding oats for fattening pigs were undertaken. A total of eight different comparisons were made of whole and ground oats when the rations carried the same proportions of each.

Six Tests Made of Value of Grinding Oats

First test. In the first of the later series of tests, 1926, the corn was coarse ground and mixed in the ratio of 4 parts corn to 1 part oats,

^aThis test was conducted under the direction of J. B. Rice, at that time Associate in Animal Husbandry.

whole oats being used for one lot and fine-ground oats for the other. These mixtures were fed free-choice with a supplemental mixture composed of tankage, linseed meal, and alfalfa meal in the ratio of 2:1:1. The check ration consisted of coarse-ground corn with supplement. A summary of the results of feeding these rations to groups of twenty pigs averaging 51 pounds each at the beginning of the test, is given in Table 7.

TABLE 7.—VALUE OF GRINDING OATS FOR GROWING-FATTENING PIGS: FIRST TEST
(Test began June 12, 1926, with 20 pigs to the lot.^a Rations were self-fed free-choice with supplement)

	Lot 1 Cracked corn	Lot 2 Cracked corn, whole oats ^b 4:1	Lot 3 Cracked corn, ground oats ^b 4:1
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight.....	52	51 ^c	51
Average final weight.....	202	200 ^c	200
Average daily gain.....	1.32	1.35 ^c	1.33
Average daily ration			
Cracked corn.....	4.98	4.38	4.00
Oats.....	.....	1.09	1.00
Supplement ^d.....	.77	.65	.62
Total.....	5.75	6.12	5.62
Feed for 100 pounds gain			
Cracked corn.....	379	325	300
Oats.....	.....	81	75
Supplement ^d	58	48	46
Total.....	437	454	421

^aSix other lots were fed oat kernels in this test (see Table 15).

^bThe oats fed in this test weighed 34 pounds per bushel. The percentage of hull was not determined, and the feeds were not analyzed.

^cFor the 19 pigs that finished.

^dSupplement contained 2 parts tankage, 1 part linseed meal, and 1 part alfalfa meal.

The differences in rate of gain on the three rations proved not to be statistically significant. The differences in economy of gain also probably were not significant. A hundred pounds of whole oats saved 67 pounds of corn and 12 pounds of supplement; while 100 pounds of ground oats saved 105 pounds of corn and 16 pounds of supplement—an apparent saving of 42 pounds of feed per 100 pounds of oats ground.

This advantage from grinding oats is doubtless considerably greater than can be expected generally. The saving of 121 pounds of total feed per hundredweight of oats ground was the highest in the entire study.

Second test. The value of grinding oats when they were mixed in three different proportions with corn (1 part oats to 4 parts corn, 1 part oats to 3 parts corn, and 1 part oats to 2 parts corn) was studied during the summer of 1927. Seven lots of 20 pigs each were used. The corn of the check lot, and the corn-oats mixtures, were fed free-choice

with the trio protein supplement, as in the preceding test. The pertinent data on this comparison have already been given in Table 2, page 122.

The differences in daily gain, as was true also in the first test, did not prove to be statistically significant. Whether or not the increase in the consumption of feed per 100 pounds of gain made by the pigs fed whole oats was due to differences in the rations or to a chance combination of uncontrolled factors could not be ascertained. The increase in feed intake per unit of gain in these three lots over the check lot varied from just over 10 percent to a little more than 15 percent. Differences of this magnitude are usually considered to be significant when the comparisons are made with as many as 20 pigs per lot. The smaller increases of feed per unit of gain, over the check lot, that accompanied the feeding of ground oats would, standing by themselves, probably not be considered significant.

In order to strengthen the comparison between whole and ground oats, and inasmuch as the differences in gain among the lots were not statistically significant, it seems legitimate to consider all the pigs that received whole oats in one group and all those that were fed ground oats in another. The averages of the data so grouped and the data for the check lot are given in Table 8.

Grinding 100 pounds of oats apparently saved in this test a total of 34 pounds of feed. The calculation of this amount is made by subtracting the feed saved by each 100 pounds of whole oats fed (50 pounds) from the amount saved by 100 pounds of ground oats (84 pounds). In the individual lots (Table 2) the feed saved by grinding

TABLE 8.—VALUE OF GRINDING OATS FOR GROWING-FATTENING PIGS: SECOND TEST
(Averages of data from Table 2)

	Check lot,* corn and supplement	Average of three lots ^a —corn, whole oats, and supplement	Average of three lots ^a —corn, ground oats, and supplement
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight.....	65	66	66
Average final weight.....	195	199	199
Average daily gain.....	1.24	1.26	1.26
Average daily ration			
Cracked corn.....	4.46	3.96	3.63
Oats.....		1.41	1.29
Supplement.....	.81	.70	.65
Total.....	5.27	6.07	5.57
Feed for 100 pounds gain			
Cracked corn.....	361	315	289
Oats.....		111	103
Supplement.....	65	55	51
Total.....	426	481	443

*Twenty pigs to the lot.

100 pounds of oats decreased from 43 pounds to 32 pounds and finally to 26 pounds as the proportion of oats to corn increased from 1:4 to 1:3 to 1:2. Just why the value of grinding should have decreased as the proportion of oats in the ration increased is not clear.

Third test. During the winter of 1927-28 the value of grinding oats was studied further with three more groups of pigs. As usual, the check ration was corn and supplement fed free-choice. The test rations consisted of mixtures of corn and oats also fed free-choice with the trio protein supplement, whole oats being used in one ration and ground oats in the other. The results of this test are shown in Table 9.

As in the previous tests, the average daily gains of the pigs were within the range of variation normal to such work. The high feed consumption per unit of gain shown for all lots was very likely the

TABLE 9.—VALUE OF GRINDING OATS FOR GROWING-FATTENING PIGS: THIRD TEST
(Test began Dec. 17, 1927, with 20 pigs to the lot.^a Rations^b were self-fed free-choice with supplement)

	Lot 1 Cracked corn	Lot 2	Lot 4 ^c
		Cracked corn and—	
		Whole oats 3:1	Ground oats 3:1
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight ^d	62	61	61
Average final weight ^d	198	199	198
Average daily gain ^d	1.22	1.17	1.16
Average daily ration			
Cracked corn.....	5.18	4.02	3.99
Oats.....	.....	1.34	1.33
Supplement ^e.....	.69	.66	.72
Total.....	5.87	6.02	6.04
Feed for 100 pounds gain			
Cracked corn.....	431	344	347
Oats.....	.....	115	116
Supplement ^e	57	57	63
Total.....	488	516	526
Composition of ration ^f	<i>percl.</i>	<i>percl.</i>	<i>percl.</i>
Dry substance.....	82.35	84.09	84.10
Protein.....	11.33	11.82	11.90
N-free extract.....	62.67	60.68	60.29
Fiber.....	2.62	4.75	4.96
Ether extract.....	3.29	3.68	3.77
Ash.....	2.44	3.16	3.18

^aTwo pigs in Lot 1, two in Lot 3, and one in Lot 2 became unthrifty from causes not related to the test and were removed.

^bThe oats fed in this test weighed 27 pounds to the bushel, and contained 33 percent of hull. The corn averaged No. 5 grade, tho some was No. 4.

^cOne additional lot was fed coarse-ground oats in this test (see Table 14).

^dFor the pigs that finished.

^eSupplement contained 2 parts tankage, 1 part linseed meal, and 1 part alfalfa meal.

^fComputed from analyses shown in Tables 26 and 27, Appendix.

result of the low grades of corn fed (Nos. 4 and 5), the light weight of oats (27 pounds to the bushel), and the rather high proportion of hulls in the oats (33 percent). A somewhat larger amount of the oats rations than of the check ration was consumed for each pound of gain made.

The feed-replacement value of oats in this test was decidedly abnormal. The saving of other feed by feeding whole oats was greater than in any other test of the series (76 pounds per 100 pounds of oats fed), while the saving by feeding ground oats was 67 pounds, a lower saving than in any of the other tests. Except for one of the early tests in which a very small proportion of oats was fed, this is the only test in the series in which whole oats actually proved superior to ground oats. There was nothing in the way the test was conducted, nor in the composition of the rations (last section, Table 9) that can be looked upon as explaining this departure from the other work. The percentage of protein in the rations was very nearly the same and the slight differences between Rations 3 and 4 with respect to the other nutrients could hardly be considered to have caused the reversal.

Fourth test. The value of grinding oats was studied further in 1929. The procedure followed was the same as in the test just described, except that the corn and oats were mixed in the ratio of 2 parts corn to 1 part oats rather than 3 parts corn to 1 part oats. Again the gains made by the pigs on the two rations proved to be essentially equal (Table 10).

One hundred pounds of whole oats fed in this test apparently saved 55 pounds of corn and 6 pounds of supplement, and 100 pounds of ground oats replaced 92 pounds of corn and 10 pounds of supplement. Grinding the oats, therefore, apparently saved a total of 41 pounds of feed for each 100 pounds of ground oats fed.

Fifth and sixth tests. The wide variation in the values obtained for grinding oats in the four tests just discussed was disconcerting, inasmuch as every effort had been made to control the experimental procedure as fully as the group-feeding method permitted.

That feed waste might be a factor in the variation was evident from the first. Feed mixtures that contained whole oats were decidedly unpalatable, and the pigs manifested their dislike by attempting in every way possible to avoid eating the oats. Beginning with the 1927 test homemade self-feeders were used that effectively checked the waste of feed directly from the self-feeders. The pigs could not be prevented, however, from taking a mouthful of the mixture, standing away from the feeder, and attempting to discard the oats—a reaction of the pigs

that was commonly observed. The feed that was thus wasted could not well be measured, and probably accounts for part of the higher feed allowance charged against the whole-oats pigs in all but one of the tests. The pigs did not react in this manner to feed mixtures that contained fine-ground oats.

In the two tests conducted in the summer of 1931 and the winter of 1931-32, a change in the method of feeding was made in hope of reducing the waste of feed which seemed inevitable when whole or course-ground oats were fed mixed with corn. The whole oats were self-fed without being mixed with other feed. And in order to encourage a reasonable consumption of the oats, the daily allowance of cracked corn was limited to 2.5 percent of the body weight of the pigs. The ground-oats ration was then made by mixing ground oats, corn, and supplement in the proportion that the whole oats, cracked corn, and supplement were consumed by the pigs of the other lot. The ground-oats mixture was then self-fed.

The hope that the feed waste would be eliminated by this method proved to be not entirely well founded. Pigs were sometimes observed

TABLE 10.—VALUE OF GRINDING OATS FOR GROWING-FATTENING PIGS: FOURTH TEST
(Test began August 3, 1929, with 20 pigs to the lot. Rations^a were self-fed free-choice with supplement)

	Lot 1 Cracked corn	Lot 2 Cracked corn and whole oats 2:1	Lot 3 Cracked corn and ground oats 2:1
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight.....	63	63	62 ^b
Average final weight.....	201	201	206 ^b
Average daily gain.....	1.24	1.32	1.28 ^b
Average daily ration			
Cracked corn.....	4.93	4.12	3.45
Oats.....	.....	2.06	1.73
Supplement ^c.....	.75	.66	.60
Total.....	5.68	6.84	5.78
Feed for 100 pounds gain			
Cracked corn.....	398	312	273
Oats.....	.....	156	136
Supplement ^c	60	50	47
Total.....	458	518	456
Composition of rations ^d	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>
Dry substance.....	86.87	87.71	87.80
Protein.....	12.27	11.88	12.27
N-free extract.....	62.90	61.42	60.98
Fiber.....	4.52	6.90	6.96
Ether extract.....	4.16	4.24	4.25
Ash.....	3.02	3.27	3.34

^aThe oats fed in this test weighed 31 pounds to the bushel and contained 29 percent of hull. The corn was largely No. 2 grade, tho a little No. 3 was fed.

^bFor the 19 pigs that finished.

^cSupplement contained 2 parts tankage, 1 part linseed meal, and 1 part alfalfa meal.

^dComputed from analyses shown in Tables 26 and 27, Appendix.

to take a mouthful of the whole oats, walk away as far as half the length of the lot, and then drop them when only partly chewed. But nevertheless somewhat less feed probably was wasted by this method of feeding than when the whole oats and corn were mixed and self-fed; and the feed that was wasted by this method was of course confined to the oats.

In both the tests in which the new procedure was used (Table 11), the pigs that received the ground-oats ration gained somewhat more rapidly than those fed whole oats. In the summer test the difference was 2.9 times its probable error, and therefore approached significance. In the winter test the difference in gain was not significant.

In both tests the pigs that were fed the ground-oats ration consumed somewhat less feed per unit of gain made than did the others.

TABLE 11.—VALUE OF GRINDING OATS FOR GROWING-FATTENING PIGS: FIFTH AND SIXTH TESTS

(Tests began June 17, 1931, and December 25, 1931, respectively, with 20 pigs to the lot)

	Fifth test		Sixth test	
	Lot 1 Cracked corn hand-fed,* whole oats and supplement self-fed	Lot 3 Feeds ground and mixed in same propor- tion as eaten by Lot 1, self-fed	Lot 1 Cracked corn hand-fed,* whole oats and supplement self-fed	Lot 2 Feeds ground and mixed in same propor- tion as eaten by Lot 1, self-fed
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight.....	71	72 ^b	69	69
Average final weight.....	195	207 ^b	202	201 ^c
Average daily gain.....	1.47	1.61 ^b	1.19	1.26 ^c
Average daily ration				
Cracked corn.....	2.88	2.75	2.91	2.75
Oats.....	2.32	2.21	2.36	2.29
Supplement ^d.....	.85	.86	.58	.59
Total.....	6.05	5.82	5.85	5.63
Feed for 100 pounds gain				
Cracked corn.....	195	173	245	223
Oats.....	157	139	199	186
Supplement ^d	58	54	49	48
Total.....	410	366	493	457
Oats, weight per bushel.....	.....	.....	34	34
Oats, percent hull.....	29	29	25	25
Corn, average grade.....	No. 3	No. 3	No. 3	No. 3
Composition of the ration*	<i>percl.</i>	<i>percl.</i>	<i>percl.</i>	<i>percl.</i>
Dry substance.....	88.27	88.29	88.04	88.08
Protein.....	14.89	15.11	13.92	14.14
N-free extract.....	58.17	57.89	59.75	59.41
Fiber.....	6.54	6.54	6.07	6.13
Ether extract.....	4.78	4.77	4.80	4.82
Ash.....	4.05	4.11	3.58	3.68

*Amount limited to 2.5 percent of the bodyweight of the pigs.

^bFor the 17 pigs that finished.

^cFor the 19 pigs that finished.

^dSupplement contained 2 parts tankage, 1 part linseed meal, and 1 part alfalfa meal.

*Computed from analyses shown in Tables 26 and 27, Appendix.

In the summer test the grinding saved, per hundredweight of oats, 16 pounds of corn, 13 pounds of oats, and 3 pounds of supplement—a total of 32 pounds of feed. The saving in the winter test was 12 pounds of corn, 7 pounds of oats, and 1 pound of supplement—a total of 20 pounds of feed.

The average saving of feed by grinding in these two tests was somewhat below the average saving in the tests in which the whole oats and corn were mixed and self-fed, if the one test in which a negative value for grinding was obtained is left out of consideration. This reduction in the apparent value of grinding indicated that the change in method of feeding really did reduce feed waste.

General Analysis of Grinding Tests

Averages of data from comparable lots in the six tests on the value of grinding oats are presented in Table 12 to show two different methods of arriving at the value of grinding oats. The first is an indirect comparison of whole and ground oats on a basis of the amount

TABLE 12.—VALUE OF GRINDING OATS FOR GROWING-FATTENING PIGS: SUMMARY OF THE SIX TESTS

(Averages of comparable data in Tables 7 to 11, inclusive.
All weights expressed in pounds)

	Cracked corn and supple- ment	Cracked corn, whole oats, and supple- ment	Cracked corn and supple- ment	Cracked corn, ground oats, and supple- ment	Cracked corn, whole oats, and supple- ment	Cracked corn, ground oats, and supple- ment
Number of lots.....	4	6	6	10	8	8
Number of pigs.....	80	120	120	200	160	160
Average initial weight.....	61	60	63	62	64	64
Average final weight.....	199	200	200	201	199	202
Average daily gain.....	1.26	1.28	1.25	1.25	1.30	1.32
Average daily ration						
Cracked corn.....	4.89	4.12	4.85	3.61	3.71	3.43
Oats.....	.....	1.47	.....	1.47	1.77	1.64
Supplement.....	.75	.67	.75	.63	.68	.67
Total.....	5.64	6.26	5.60	5.71	6.16	5.74
Feed for 100 pounds gain						
Cracked corn.....	392	324	394	292	289	268
Oats.....	.....	116	.....	120	137	126
Supplement.....	60	52	60	50	53	51
Total.....	452	492	454	462	479	445
Feed saved by 100 pounds oats						
Corn.....	.....	59	.....	85	.....	.....
Supplement.....	.....	7	.....	8	.....	.....
Feed saved by grinding 100 pounds oats						
Corn.....	.....	.....	.....	26	.....	17
Oats.....	.....	.....	.....	.....	.....	9
Supplement.....	.....	.....	.....	1	.....	2

of feed replaced by each; the second is a direct comparison of whole and ground oats.

Averages of the weights, gains, and feed consumption of four groups of pigs that received only corn and supplement, and of six similar groups in the same experiments that were fed corn, whole oats, and supplement are given in the first and second columns of Table 12. Similar data for the lots that received ground oats are given in the third and fourth columns. Altho a slightly higher proportion of ground oats than whole oats was fed, the difference was evidently much too small to invalidate a comparison of the two sets of data (see page 120). The differences in daily gain made by the pigs fed whole oats and by those fed ground oats were insignificant, a fact which justifies the use of the method of comparison employed in the following paragraph.

According to the indirect comparison (first and second columns), 100 pounds of whole oats fed in these tests saved 59 pounds of corn and 7 pounds of protein supplement, while 100 pounds of ground oats (third and fourth columns) saved 85 pounds of corn and 8 pounds of supplement. The difference, 26 pounds of corn and 1 pound of supplement, supposedly was due to grinding 100 pounds of oats.

The direct comparison of whole and ground oats (fifth and sixth columns) gives average data from eight comparisons in which whole and ground oats were compared directly in the same experiments. As in the other comparisons, the rates of gain did not differ materially, and the pigs on the ground-oats ration ate only 7 percent less feed than the others for each pound of gain made. The amount of the whole-oats ration replaced by 100 pounds of ground oats, or, in other words, the amount of feed apparently saved by the grinding, was 17 pounds of corn, 9 pounds of oats, and 2 pounds of supplement—a total of 28 pounds.

Thus the two methods of comparing the whole-oats and the ground-oats indicated practically the same value for the grinding of the oats: 27 pounds of feed saved according to the indirect comparison, and 28 pounds according to the direct comparison.

Tests at Other Stations on Grinding Oats

Most feeding tests at other stations involving a comparison of ground oats and whole oats have, during recent years, indicated a somewhat larger saving for grinding the oats than has been shown by the Illinois experiments, Vestal,^{21, 23*} at the Purdue Station, reported two tests the data of which included comparisons of whole and fine-ground oats. The rations contained corn and oats mixed in the pro-

portion of 3 parts corn to 1 part oats. In one test the supplement was mixed with the grain and the rations were hand-fed, while in the other it was offered free-choice with the grain mixtures. The pigs in the first test averaged at the beginning 74 pounds in weight and were fed 10 in a lot for 110 days. The pigs in the second test started at an initial weight of 60 pounds and were fed for 90 days. The gain of the pigs of the first test was for some reason much below normal for pigs of that weight—check lot, .88 pound per head daily; whole oats, .82 pound; and fine-ground oats, 1.05 pounds. The saving of feed indicated by these tests to have resulted from grinding 100 pounds of oats was 46 pounds and 50 pounds respectively when the lots that received whole oats and those that received fine-ground oats are compared directly.

Robison,^{14*} at the Ohio Station, fed 110-pound pigs to weights of approximately 236 pounds, and 65-pound pigs to weights of 206 to 209 pounds, in lots of eight, on rations that contained somewhat over 20 percent of oats, whole oats in one lot and ground oats in the other. Grinding 100 pounds of oats saved 48 pounds of feed with the heavier pigs and 56 pounds with the light pigs. In a third Ohio test,^{18*} however, with 58-pound pigs, grinding oats saved only 31 pounds of feed per hundredweight of oats. In other Ohio tests grinding oats saved only 10 pounds of feed in one test^{13*} and none in another,^{18*} and in still another test^{14*} ground oats were materially less valuable than whole oats.

Grinding oats saved less feed in three tests reported by Robison^{14, 18*} when the oats were fed as the sole grain (with supplement) than when they replaced only a part of the corn. In another of his trials^{18*} the reverse was true.

In the early work at the Wisconsin Station previously mentioned (page 115), in which mixtures of corn and oats were fed without protein supplement, grinding 100 pounds of oats saved 67 pounds of feed when the oats were fed with corn in the ratio of 1 part oats to 2 parts corn and 47 pounds when they were fed with corn in the higher ratio of 2 parts oats to 1 part corn.

In view of the findings of other stations, it seems safe to conclude that the rather more conservative findings at the Illinois Station do not overstate the value to be derived from grinding oats under practical feedlot conditions. The Illinois tests indicate that if 100 pounds of oats can be ground fine at a cost below the value of 25 to 30 pounds of feed, it will pay to grind the oats rather than to feed them unground.

COARSE OR FINE GRINDING OF OATS

That coarse-ground oats were unpalatable to pigs, and that feed was wasted by feeding such oats, either free-choice or in mixtures that contained a large proportion of oats, became evident early in the study. Consequently the value of grinding oats to different degrees of fineness was tested in only two experiments.

First test. In the first test, conducted during the winter of 1926-27, oats, coarse ground in one ration and fine ground in another, were fed free-choice with shelled corn and a protein supplement to two

TABLE 13.—COARSE OR FINE GRINDING OF OATS FOR GROWING-FATTENING PIGS: FIRST TEST

(Test began February 5, 1927, with 20 pigs to the lot. Rations^a were self-fed free-choice)

	Lot 1 Shelled corn, <i>coarse</i> -ground oats, and supplement	Lot 2 Shelled corn, <i>fine</i> -ground oats, and supplement
	<i>lbs.</i>	<i>lbs.</i>
Average initial weight ^b	53	53
Average final weight ^b	199	195
Average daily gain ^b	1.30	1.13
Average daily ration		
Shelled corn.....	3.82	2.44
Ground oats.....	1.32	2.20
Supplement ^c.....	.63	.55
Total.....	5.77	5.19
Feed for 100 pounds gain		
Shelled corn.....	299	218
Ground oats.....	103	197
Supplement ^c	49	49
Total.....	451	464

^aThe oats fed in this test contained 90.07 percent of dry substance and 12.12 percent of fiber. The corn was of poor quality altho its actual grade was not recorded.

^bFor the 19 pigs that finished in each lot.

^cSupplement contained 2 parts tankage, 1 part linseed meal and 1 part alfalfa meal.

groups of twenty 53-pound pigs. The quality of the corn was only fair, and the oats also were below average and contained a little over 12 percent of fiber.

The pigs in this test ate just a little more than one-third as much *coarse*-ground oats as corn, and almost as much *fine*-ground oats as corn (Table 13). The more rapid gains of the pigs that were fed coarse-ground oats (the difference in gain is statistically significant) was no doubt caused by the difference in the amount of oats consumed rather than by the difference in the degree of fineness to which the oats were ground.

Second test. The second test of the value of grinding oats to

different degrees of fineness was conducted during the winter of 1927-28. Whole, coarse-ground, and fine-ground oats were each mixed with cracked corn in the ratio of 1 part oats to 3 parts corn. These mixtures were then fed free-choice with a protein supplement. A check lot of pigs was fed only cracked corn and supplement.

The quality of the corn fed in this test again was only fair, averaging about No. 5 grade. The oats weighed a little under 27 pounds a bushel and contained 33 percent hull and a little over 12 percent fiber.

The differences in rates of gain between lots (Table 14) were not significant and those that did exist were in favor of the coarse-ground oats. The differences in amount of feed eaten for each pound of gain made were likewise probably insignificant. As in most of the other tests, the pigs that received no oats ate less feed for each unit of gain made than did the pigs that were fed oats.

TABLE 14.—COARSE OR FINE GRINDING OF OATS FOR GROWING-FATTENING PIGS:
SECOND TEST
(Test began December 17, 1927, with 20 pigs to the lot.^a Rations^b were self-fed free-choice with supplement)

	Lot 1 Cracked corn	Lot 2	Lot 3	Lot 4
		Cracked corn and—		
		Whole oats 3:1	Coarse oats 3:1	Fine oats 3:1
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight ^c	62	61	59	61
Average final weight ^c	198	199	206	198
Average daily gain ^c	1.22	1.17	1.25	1.16
Average daily ration				
Cracked corn.....	5.18	4.02	4.09	3.99
Oats.....	.....	1.34	1.36	1.33
Supplement ^d.....	.69	.66	.65	.72
Total.....	5.87	6.02	6.10	6.04
Feed for 100 pounds gain				
Cracked corn.....	431	344	338	347
Oats.....	.....	115	113	116
Supplement ^d	57	57	54	63
Total.....	488	516	505	526
Composition of the ration ^a	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>
Dry substance.....	82.35	84.09	83.66	84.10
Protein.....	11.33	11.82	11.47	11.90
N-free extract.....	62.67	60.68	60.49	60.29
Fiber.....	2.62	4.75	4.94	4.96
Ether extract.....	3.29	3.68	3.71	3.77
Ash.....	2.44	3.16	3.05	3.18

^aTwo pigs in each of Lots 1, 3, and 4, and one pig in Lot 2, became unthrifty and were removed.

^bThe oats fed in this test weighed 27 pounds a bushel, and contained 33 percent of hull. The corn averaged No. 5 grade, tho some No. 4 was fed.

^cFor the pigs that finished.

^dSupplement contained 2 parts tankage, 1 part linseed meal, and 1 part alfalfa meal.

^eComputed from analyses shown in Tables 26 and 27, Appendix.

That the mixtures containing the whole and the coarse-ground oats were less palatable than the mixture containing fine-ground oats was indicated by the attempts of the pigs to separate and discard the whole and the coarse-ground oats. But when fine-ground and coarse-ground oats made up equal proportions of the ration, the degree of fineness of grinding apparently did not affect the feeding value of the oats.

Work at other stations. The Indiana Station^{21, 23*} has reported two tests in which coarse-, medium-, and fine-ground oats were compared. The oats were fed with corn in the ratio of 1 part oats to 3 parts corn, a protein supplement being fed in addition. While these reports contain no analysis of the probable significance of the differences in rate and economy of gain made by the different lots of pigs, the differences were small enough to fall within the range of experimental error. Assuming this to be the case, the Indiana data agree with data from the Illinois tests in indicating that the degree of fineness of grinding oats does not in itself affect their nutritive value.

Disadvantages of fine grinding. Two practical aspects of the grinding of oats for swine should not be lost sight of. First, pigs that are fed fine-ground oats of good quality free-choice with corn and supplement may eat such a large proportion of oats as to reduce materially their rate and economy of gain below that to be expected from a ration of corn and supplement, or corn, whole oats, and supplement. Second, the power cost of grinding oats to a fine state ($\frac{3}{32}$ -inch screen in a hammer mill) is about double that required to grind the oats coarse ($\frac{5}{16}$ -inch screen on the same hammer mill).

VALUE OF OAT KERNELS IN SWINE RATIONS

The palatability of a feed is an important factor in its value in the ration, since the amount of feed that an animal can and will eat in a given time influences the amount required to produce a given gain. The relative unpalatability of oats for hogs was observed by those early investigators whose work on oats was discussed in foregoing sections of this bulletin. In one of the early tests at the Illinois Station (Table 6) in which oats were fed to pigs averaging 93 pounds in weight at the beginning of the test, the pigs that were fed whole oats and tankage free-choice ate only 3.6 pounds of oats per head daily during a 140-day feeding period, whereas the pigs that were fed corn and tankage ate 4.4 pounds of corn daily.

The oats-fed pigs ate a pound of tankage per head daily (much more than they needed), while the corn-fed pigs ate only .7 pound, which is further evidence of the unpalatability of oats.

Anyone who studies pigs eating whole oats either alone or in mixtures with other farm grains cannot escape being impressed by the apparent dissatisfaction shown by the pigs with the oats. That it is the hull of the oats which the pigs dislike, is evident from the following data from three tests at the Illinois Station which show the proportion of oats that pigs consumed when oats prepared in four different ways were fed free-choice with corn and supplement:

<i>Feeds</i>	<i>Proportion of oats eaten when fed—</i>			
	<i>Whole</i>	<i>Coarse-ground</i>	<i>Fine-ground</i>	<i>Kernels</i>
	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>
Corn.....	82	66	47	30
Oats.....	8	23	42	63
Supplement.....	10	11	11	7

According to the consumption of oats in these four rations, any preparation of the oats that causes the hulls to be less conspicuous to the pigs renders the oats more palatable; and when no hulls are present at all (oat kernels), the oats are most palatable.

The pigs to which the above rations were fed weighed between 51 and 54 pounds each when the tests began. Grinding was done by a hammer mill, a $\frac{5}{16}$ -inch screen being used for the coarse grinding and a $\frac{3}{32}$ -inch screen for the fine grinding. The hulls were very noticeable in the coarse-ground oats, but in the fine-ground oats both the hulls and the kernels were pulverized to a floury mass.

The quality of the oats and their freedom from disease also naturally affect their palatability for swine. That soaking oats does not make them more palatable was shown by Evvard^{3*} in feeding experiments at the Iowa Station.

One of the principal reasons for undertaking in 1926 additional work on the question of feeding oats to swine was the fact that farm-size oat-hulling machines^a became available about that time, and

*Before these machines came into use the hulling of oats was confined to the breakfast-food industry. The oats used for this purpose are especially selected for size and quality and are cleaned and kiln dried before being hulled. Such oats can be hulled with greater ease and completeness than can the average run of oats on the farm. The hulling machines used in these factories are of a size and cost that are prohibitive for general use on farms.

Shortly after the development of the small hulling machines, medium-sized hullers suitable for operation in elevators and small feed mills, or for mounting on trucks to be moved from farm to farm for custom hulling, became available.

The early, small machines were not very efficient. One that was purchased by the Illinois Station in the spring of 1926 (probably the first used in this state) recovered as kernels only 52 percent of the oats put thru it for the first feeding test in which it was used. The 52 percent that was recovered consisted of some

seemed, therefore, to open up a way of utilizing more oats in swine feeding. In all, seven tests of hulled and hull-less oats were made.

Feeding Tests With Steel-Cut Oats

In this test the oat kernels, purchased under the name of "steel-cut oats" (broken kernels from the oatmeal industry), were of good quality and contained no noticeable amount of foreign matter. They were mixed with cracked corn in ratios of 1 part oats to 4 parts corn, 1 part oats to 2 parts corn, and 1 part oats to 1 part corn, and these mixtures were then fed free-choice with a protein supplement. In a fourth ration the cracked corn, oat kernels, and supplement all were fed free-choice. Data are given in Table 15.

Two additional lots (Lots A and B) of 18 pigs each were put on feed six weeks after the main test had started, in order to compare the palatability and value of "steel-cut oats" and oats hulled by a farm-size oat-hulling machine.

The differences in daily gain among the various lots of pigs in this test did not prove to be statistically significant. Whether or not this was true also for the differences in amounts of feed eaten for unit of gain made could not, of course, be tested. Differences as great as those between Lot 1, in which no oat kernels were fed, and the groups that received this feed are large enough to be of practical importance.

The feed-replacing value of the oat kernels in this test was very uniform from lot to lot, except for the extremely high value indicated by Lot 4, and at least part of the difference in this case was assumed to be due to chance variations. If this is true, the assigning of the entire difference to such a small portion of this ration as the oat kernels comprized would in itself exaggerate the difference unduly.

If, therefore, Lot 4 is disregarded, the data contain no strong suggestion that the proportion of oat kernels in the ration was a factor

87 percent kernels, 8 percent unhulled oats, and 5 percent free oat hulls. A year later another machine returned 56 percent of the oats put into it, and unhulled oats comprized 17 percent of the materials recovered. The oats put into the latter machine actually contained 68 percent of kernels, as shown by a hand-hulled sample. The efficiency of these machines, however, both in the percentage of recovery and in the purity of the recovered product, was materially increased by the introduction of the Carter disk into the portable hulling machines as a device for separating out the kernels after they are freed from the hulls. One such machine, on which five runs totaling about 3,800 bushels were checked, recovered as hulled oats 67 percent of the weight of the oats put into the machine. The recovered material contained from 4 to 9 percent of unhulled oats and free oat hulls. In these tests this machine actually recovered as shelled kernels 88 percent of the oat kernels that were put into it.

TABLE 15.—VALUE OF OAT KERNELS* WHEN FED AS DIFFERENT PROPORTIONS OF THE RATIOMS OF GROWING-FATTENING PIGS: FIRST TEST
(Lots 1, 4, 5, 6, and 7 were started June 12, 1926, with 20 pigs to the lot;^b Lots A and B, July 24, 1926, with 18 pigs to the lot. The rations were self-fed)

	Lot 1 Cracked corn	Lot 4 ^b	Lot 5	Lot 6	Lot 7 Cracked corn, steel-cut oats, and supple- ment, all free-choice	Lot A Shelled corn, steel-cut oats, and supple- ment, all free-choice	Lot B Shelled corn, hulled oats, and supple- ment, all free-choice
		Mixtures of cracked corn and —					
		Steel-cut oats 4:1	Steel-cut oats 2:1	Steel-cut oats 1:1			
		Supplement fed free-choice					
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Average initial weight ^c	52	51	51	52	52	48	48
Average final weight ^c	202	198	200	200	200	198	204
Average daily gain.....	1.32	1.37	1.33	1.33	1.38	1.39	1.45
Average daily ration.....							
Cracked corn.....	4.98	3.51	3.06	2.19	1.41	1.34	2.61
Oat kernels.....	.....	.88	1.53	2.19	2.94	2.87	2.29
Supplements ^d.....	.77	.52	.40	.39	.32	.45	.48
Total.....	5.75	4.91	4.99	4.77	4.67	4.66	5.38
Feed for 100 pounds gain.....							
Cracked corn.....	379	257	231	166	102	98	180
Oat kernels.....	.....	64	115	166	213	211	158
Supplement ^d	58	38	30	29	24	33	33
Total.....	437	359	376	361	339	342	371

*The oat kernels were in the form of "steel-cut" oats except in Lot B, where hulled oats were fed. The hulled oats contained 87 percent naked kernels and 13 percent unhulled oats and free oat hulls.

^bTwo other lots in this test were fed whole and ground oats (see Table 7). One pig each in Lots 4, 6, and A became unthrifty and was removed from the test.

^cFor the pigs that finished.

^dSupplement contained 2 parts tankage, 1 part linseed meal, and 1 part alfalfa meal.

in the amount of other feed replaced by a given amount of the oats. On the average, 100 pounds of oat kernels fed to the three remaining lots replaced 129 pounds of corn and 18 pounds of supplement, which is a very high value for this feed.

A very similar feed saving is indicated for each 100 pounds of oat kernels and hulled oats fed in Lots A and B. However, a comparison of these lots with the check lot of the main test is open to criticism, since the pigs of Lots A and B differed from those in the check lot in the distribution of the sexes, in the breeds represented, and somewhat also in the time of going on feed. Again, shelled corn was fed in Lots A and B, while coarse-ground corn was fed the pigs in the check lot. But in spite of these differences in the treatment of the pigs, the indicated value of "steel-cut oats" and of hulled oats as fed in the two later lots agreed remarkably well with the value arrived at in the main test.

Feeding Test With Hulled Oats

With the data of the foregoing test and the experience gained with the hulling machine as a foundation, an experiment involving 200 pigs was conducted during the following summer (1927) to compare whole, ground, and hulled oats in the ration of growing-fattening pigs. Each of the three forms of oats was mixed with corn in the ratios of 1 part oats to 4 parts corn, 1 part oats to 3 parts corn, and 1 part oats to 2 parts corn, and the mixtures were self-fed free-choice with a protein supplement to lots of twenty 68-pound pigs. The pigs in the check lot received cracked corn fed free-choice with supplement.

Since the lots that were fed whole and ground oats have already been discussed (see Table 2), only the data on the value of hulled oats are presented here. The differences in rate of gain (Table 16) among the four groups of pigs proved not to be significant. It seems unlikely also that the relatively small differences in amounts of feed eaten for 100 pounds of gain are significant.

Just why the feed saving that resulted from adding hulled oats to the rations in this test was so much lower than in the preceding test is not clear. The hulled oats failed to replace their own weight of other feed in Lots 8 and 9 and saved only 13 percent above their own weight in Lot 10. The corn fed in both of these tests was of poor quality, tho its actual grade was not recorded.

Feeding Tests With Hull-less Oats

Because of discouraging experiences with four farm-size hulling machines, one of which was tested in some detail by the Department of

TABLE 16.—VALUE OF OAT KERNELS^a WHEN FED AS DIFFERENT PROPORTIONS OF THE RATIONS OF GROWING-FATTENING PIGS: SECOND TEST
(Test began June 25, 1927, with 20 pigs to the lot.^b The rations^c were self-fed free-choice with supplement)

	Lot 1 Cracked corn only	Lot 8	Lot 9	Lot 10
		Mixtures of cracked corn and—		
		Hulled oats 4:1	Hulled oats 3:1	Hulled oats 2:1
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight ^d	68	69	67	67
Average final weight ^d	195	200	204	204
Average daily gain ^d	1.24	1.31	1.36	1.37
Average daily ration				
Cracked corn.....	4.46	4.06	3.99	3.33
Hulled oats.....	.....	1.01	1.33	1.67
Supplement ^e.....	.81	.67	.61	.50
Total.....	5.27	5.74	5.93	5.50
Feed for 100 pounds gain				
Cracked corn.....	361	316	292	248
Hulled oats.....	.....	79	98	124
Supplement ^e	65	52	44	38
Total.....	426	447	434	410

^aThe oat kernels fed in this test were in the form of hulled oats.

^bPigs became unthrifty and were removed from the test as follows: Lot 1, two pigs; Lot 8, four pigs; Lot 9, two pigs; Lot 10, one pig. Six other lots were fed whole and ground oats in this test (see Table 2).

^cThe hulled oats fed contained 81 percent of groats, 19 percent of unhulled oats and free oat hulls, 93.09 percent of dry substance, 15.31 percent of protein, and 5.38 percent of fiber. The corn was of poor quality, tho its actual grade was not recorded.

^dFor the pigs that finished.

^eSupplement contained 2 parts tankage, 1 part linseed meal, and 1 part alfalfa meal.

Agricultural Engineering of the University of Illinois, the tests on the value of hulled oats were discontinued. The simplest and most logical method of eliminating the trouble and losses of grain that occurred with hulling, without at the same time giving up the use of oat kernels in swine rations, seemed to be to grow a variety of oats that threshes a naked kernel. Accordingly some study was made of the use of hull-less oats in swine rations.^a

1929-30 test. During the winter of 1929-30 a test was made of the value of hull-less oats when fed in different proportions in the rations of growing-fattening pigs. Mixtures containing hull-less oats and corn (both coarse-ground) in ratios of 1 part oats to 2 parts corn and 1 part oats to 1 part corn were fed free-choice with a protein sup-

^aWhile no careful study was made of the culture of hull-less oats, those grown for this study yielded a somewhat greater weight of kernels per acre than was obtained from adjoining fields of regular oats. These very limited observations indicated that the hull-less oats germinated less vigorously than the others, were somewhat more subject to disease, and were more difficult to harvest and to thresh without waste.

plement. Coarse-ground hull-less oats were also fed free-choice with cracked corn and supplement.

The differences in daily gain from lot to lot (Table 17) are not significant statistically. It is doubtful also whether the differences of 5 to 8 percent in feed eaten per hundredweight of gain made are significant, tho the fact that the three lots that received hull-less oats all ate less total feed for a unit of gain than did the check lot is suggestive

TABLE 17.—VALUE OF OAT KERNELS^a WHEN FED AS DIFFERENT PROPORTIONS OF THE RATIONS OF GROWING-FATTENING PIGS: THIRD TEST

(Test began January 25, 1930, with 20 pigs to the lot. Rations^b were self-fed free-choice with supplement)

	Lot 1 Cracked corn	Lot 2	Lot 3	Lot 4
		Cracked corn and hull-less oats		
		2:1	1:1	Free-choice
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight.....	77	77	77	77
Average final weight.....	197	203	198	196
Average daily gain.....	1.55	1.64	1.58	1.54
Average daily ration				
Cracked corn.....	6.27	4.21	2.97	4.25
Ground hull-less oats.....	.....	2.10	2.96	1.60
Supplement ^c.....	.80	.58	.52	.62
Total.....	7.07	6.89	6.45	6.47
Feed for 100 pounds gain				
Cracked corn.....	404	257	188	276
Ground hull-less oats.....	.....	128	187	104
Supplement ^c	52	35	33	40
Total.....	456	420	408	420
Composition of ration ^d	<i>percl.</i>	<i>percl.</i>	<i>percl.</i>	<i>percl.</i>
Dry substance.....	82.33	84.08	85.08	83.81
Protein.....	11.95	12.97	13.95	13.00
N-free extract.....	61.71	62.33	62.02	61.91
Fiber.....	3.19	3.07	3.10	3.14
Ether extract.....	2.80	3.10	3.28	3.06
Ash.....	2.68	2.61	2.73	2.70

^aThe oat kernels fed in this test were in the form of hull-less oats.

^bThe hull-less oats fed in this test weighed 45 pounds per bushel. They were not pure hull-less, inasmuch as 20 percent by weight were of the ordinary variety in the hull. The corn varied from No. 4 to No. 6 grade, with an average of No. 5.

^cSupplement contained 2 parts tankage, 1 part linseed meal, and 1 part alfalfa meal.

^dComputed from analyses shown in Tables 26 and 27, Appendix.

that the hull-less oats were somewhat more valuable than corn.

The coarse-ground hull-less oats proved to be less palatable than corn in this test, for the pigs ate over 2.5 times more cracked corn than ground hull-less oats when the feeds were offered free-choice.^a

^aThe possibility of a slight infestation of the oats with scab being a factor in their consumption was not ruled out, since no check was made on this point. Subsequent observations suggest that this might easily have been a factor.

The proportion of hull-less oats in the ration did not appear to affect the amount of feed saved by each unit of the oats fed. One hundred pounds of hull-less oats fed in this test saved from 126 to 135 pounds of other feed, about 10 percent of which was protein supplement. The saving in supplement was apparently due to the voluntarily lower daily consumption of supplement by the pigs that received hull-less oats in addition to corn.

This reduction in the supplement intake by the pigs that received hull-less oats as a part of their ration was not great enough, however, to bring the total protein of the hull-less oats rations (12.97 to 13.94 percent, Table 17) down to the level of protein in the check ration (11.96 percent). The higher protein intake apparently did not result in significantly more rapid gains.

1930-31 test. In a second test of the value of hull-less oats, during the winter of 1930-31, the oat kernels were compared not only with a ration that contained no oats, but with one that contained a like amount of oat kernels fed as unhulled oats. Corn and the unhulled oats were ground and mixed in the ratio of 2 parts corn to 1 part oats, and the mixture was fed free-choice with a protein supplement. To maintain this same ratio between corn and oat kernels proper required that the corn and hull-less oats be mixed in the ratio of 2.8 parts corn to 1 part oats. This mixture was likewise fed free-choice with the supplement. The chemical composition of the three rations was very similar, as may be seen in the last section of Table 18.

The differences in the average daily gains of the different groups of pigs were not statistically significant. Feed consumption for a unit of gain also was so uniform as to suggest that the rations were substantially equal in feeding value.

The hull-less oats showed a much lower value than in the preceding test, 100 pounds of them replacing only 90 pounds of other feed, compared with an average of 130 pounds in the earlier test (Table 17).

The reasons for this very marked difference in the saving of feed in the two tests are not clear. The pigs in the 1929-30 test, it is true, were 9 pounds heavier at the start and gained very much more rapidly than the pigs of the second test. And the corn used in the second test (averaging No. 4) was of slightly higher quality than that fed in the first (averaging No. 5). But these conditions hardly explain the lower replacement value of the hull-less oats in the 1930-31 test, for the saving of feed by the ground unhulled oats^a fed in the second test,

^aThe unhulled oats used were high in quality, weighing 34 pounds a bushel and containing only 29 percent of hulls.

TABLE 18.—VALUE OF OAT KERNELS^a WHEN FED AS DIFFERENT PROPORTIONS OF THE RATIONS OF GROWING-FATTENING PIGS: FOURTH TEST
(Test began January 22, 1931, with 20 pigs to the lot.^b Rations^c were self-fed free-choice with supplement)

	Lot 1 Cracked corn	Lot 2	Lot 3
		Cracked corn and	
		Ground oats 2:1	Hull-less oats 2.8:1 ^d
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight ^e	69	68	68
Average final weight ^e	198	199	204
Average daily gain ^e	1.23	1.17	1.21
Average daily ration			
Cracked corn.....	4.77	3.35	3.92
Ground oats.....	.....	1.67	.....
Ground hull-less oats.....	.....	.....	1.39
Supplement ^f.....	.72	.46	.49
Total.....	5.49	5.48	5.80
Feed for 100 pounds gain			
Cracked corn.....	407	286	325
Ground oats.....	.....	143	.....
Ground hull-less oats.....	.....	.....	115
Supplement ^f	62	39	40
Total.....	469	468	480
Composition of rations ^g	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>
Dry substance.....	86.83	87.65	88.01
Protein.....	13.58	12.80	13.65
N-free extract.....	62.82	62.78	64.69
Fiber.....	2.50	4.61	2.39
Ether extract.....	5.02	4.46	4.80
Ash.....	2.93	3.00	2.48

^aThe oat kernels fed in this test were in the form of hull-less oats.

^bTwo pigs in Lot 1 and one in Lot 3 became unthrifty and were removed from the test.

^cThe oats weighed 34 pounds a bushel and contained 29 percent hulls. The hull-less oats weighed 52 pounds a bushel and contained 4 percent oats in the hull. The corn was largely No. 4 grade, tho some No. 3 was fed.

^dThe cracked corn and hull-less oats were mixed in the proportion that the corn and *oat kernels* occurred in the mixture of corn and ground oats that was fed Lot 2.

^eFor the pigs that finished.

^fSupplement contained 2 parts tankage, 1 part linseed meal, and 1 part alfalfa meal.

^gComputed from analyses shown in Tables 26 and 27, Appendix.

Lot 2, was even higher—101 pounds of total feed saved for each 100 pounds of ground oats fed—than the average saving made by ground oats in other tests. Nor can unpalatability of the hull-less oats be advanced as a reason for their low value, for the daily consumption of the hull-less oats mixture was somewhat higher than of the other rations.

Further Tests With Hulled Oats

Because of the wide differences thus far obtained for the feeding value of oat kernels, further tests with hulled oats were begun in 1932. The oat kernels for these later tests were obtained by hulling the oats in an "Ideal" oat-hulling machine that was mounted on a truck and used for custom hulling. The kernels recovered were remarkably free

from unhulled oats and oat hulls. Ninety-three percent of the hulled oats fed in these tests consisted of pure oat kernels.

1932-33 test. During the winter of 1932-33 four groups of 20 pigs each were self-fed in drylot the feed mixtures outlined below. The average weight of the pigs at the beginning was 71 pounds, and each group was fed until an average final weight of approximately 200 pounds was reached. The feeding was done in a central hog house with a concrete floor. Each lot of pigs had a 10-by-16-foot space inside the barn and had access, on the less severe days, to an 8-by-16-foot concrete runway outside the barn.

Rations.—The feeds were mixed in the following proportions and self-fed. Each ration contained approximately 16 percent crude protein.

Lot 1		Lot 3	
Ground corn.....	4 parts	Ground corn, 1 }	7 parts
Supplement.....	1 part	Hulled oats, 2 }	
		Supplement.....	1 part
Lot 2		Lot 4	
Ground corn, 2 }	5 parts	Hulled oats.....	12 parts
Hulled oats, 1 }		Supplement.....	1 part
Supplement.....	1 part		

The supplement contained tankage, soybean oil meal, and alfalfa meal in the ratio of 2:1:1. Water and a mineral mixture composed of equal parts of limestone, bone meal, and salt were available to the pigs at all times.

Results.—Before the end of the test a number of the pigs of Lot 4 developed “stiffness,” which was thought might have resulted from the inclusion of only a small proportion of alfalfa meal in their ration—somewhat less than 2 percent. The proportion of alfalfa meal was small because only enough of the trio supplement was used in each feed mixture to bring the protein content of the entire mixture up to 16 percent.^a

A summary of the weights, gains, and feed consumption of the various lots of pigs is given in Table 19. The differences in gain between Lots 1 and 2; 2 and 4; and 3 and 4 were statistically significant, but the other differences were not.

According to the consumption of feed in the different lots, hulled oats are somewhat more efficient for pork production than is corn,

^aRobison in 1930 (Ohio Agr. Exp. Sta. Mo. Bul. 145 pp. 104, 105) reported the development of stiffness in pigs that were fed in drylot a ration that consisted largely of hulled oats. Cod-liver oil effected a cure in these pigs. Robison also reported that “including three percent of ground alfalfa in the ration prevented the development of lameness in pigs of a second group similarly fed.” Alfalfa meal, however, proved ineffective in the 1933-34 test at the Illinois Station.

TABLE 19.—VALUE OF OAT KERNELS^a WHEN FED AS DIFFERENT PROPORTIONS OF THE RATIONS OF GROWING-FATTENING PIGS: FIFTH TEST(Test began December 9, 1932, with 20 pigs to the lot. The rations^b were mixed and self-fed)

	Lot 1	Lot 2	Lot 3	Lot 4
	Ground corn, hulled oats, supplement			
	4:0:1	10:5:3	7:14:3	0:12:1
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight.....	71 ^o	71 ^o	71	71 ^o
Average final weight.....	201 ^o	201 ^o	198	195 ^o
Average daily gain.....	1.24 ^o	1.42 ^o	1.40	1.11 ^o
Average daily ration				
Cracked corn.....	4.38	3.31	1.65	.....
Hulled oats.....	.....	1.65	3.30	3.87
Supplement ^d	1.09	.99	.70	.32
Total.....	5.47	5.95	5.65	4.19
Feed for 100 pounds gain				
Cracked corn.....	361	234	117	.....
Hulled oats.....	.....	117	235	352
Supplement ^d	90	70	50	29
Total.....	451	421	402	381
Composition of ration ^c	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>
Dry substance.....	83.75	87.34	89.64	90.04
Protein.....	17.06	15.62	16.00	16.19
N-free extract.....	55.74	59.79	61.59	61.93
Fiber.....	4.50	4.09	3.38	3.28
Ether extract.....	2.67	4.25	5.29	5.76
Ash.....	3.78	3.59	3.38	2.88

^aThe oat kernels fed in this test were in the form of hulled oats. They weighed 60 pounds a bushel, and contained 4 percent of unhulled oats and free oat hulls.^bThe corn fed in the test was largely No. 2 grade, tho a little No. 3 was fed.^cFor the 19 pigs that finished.^dSupplement contained 2 parts tankage, 1 part linseed meal, and 1 part alfalfa meal.^eComputed from analyses shown in Tables 26 and 27, Appendix.

for as the proportion of hulled oats increased the total feed eaten for each 100 pounds of gain made declined progressively. Between Lots 2 and 3, 2 and 4, and 3 and 4 this difference amounted almost exactly to the difference in amount of supplement (20 pounds) required to equalize the protein content of the rations consumed, while in Lot 1, 30 pounds more feed was eaten than in Lot 2 for each 100 pounds of gain made.

The saving of feed in the hulled-oats rations averaged 105 pounds of corn and 17 pounds of supplement for each 100 pounds of hulled oats fed, when results from these were compared with the check lot that received only corn and supplement. This saving was very uniform regardless of the proportion of hulled oats in the ration.

1933-34 test. In the winter of 1933-34 a direct repetition of the preceding test, except for slight modifications of the rations that seemed likely to render the test somewhat more conclusive, was made.

Five percent of alfalfa meal was included in all rations in the rather vague hope that this might prevent the development of "stiffness."

Rations.—From the beginning of the test until the pigs reached weights of approximately 120 pounds, the feeds were mixed in the following proportions and were self-fed. Each ration contained 15 to 16 percent crude protein.

<i>Feeds</i>	<i>Lot 1 perct.</i>	<i>Lot 2 perct.</i>	<i>Lot 3 perct.</i>	<i>Lot 4 perct.</i>
Ground corn.....	83	58	30	..
Hulled oats.....	..	28	59	93
Tankage.....	12	9	6	2
Alfalfa meal.....	5	5	5	5

When the pigs weighed about 120 pounds each, the proportion of crude protein in the rations was reduced to 14 to 15 percent by the changes indicated below. These second feed mixtures were fed from that time until the test was concluded:

	<i>Lot 1 perct.</i>	<i>Lot 2 perct.</i>	<i>Lot 3 perct.</i>	<i>Lot 4*</i> <i>perct.</i>
Ground corn.....	85	59	31	..
Hulled oats.....	..	29	60	95
Tankage.....	10	7	4	..
Alfalfa meal.....	5	5	5	5

Water and a mineral mixture composed of equal parts of limestone, bone meal, and salt were available to the pigs at all times.

The chemical compositions of the above rations are shown in Table 20. The moisture content of the corn was somewhat higher than of the hulled oats, and therefore the Lot 1 ration had a dry-matter and protein content somewhat lower than the others. And since the ether extract of oat kernels was considerably higher than of the corn, the rations containing oats had an ether-extract percentage above that of the check ration. Again, as the proportion of oat kernels in the ration increased, less tankage was required to bring the protein to the desired level, and this lower proportion of tankage resulted in a lower percentage of ash in the ration. In this connection it is interesting to note the increased consumption of the mineral supplement (which was fed free-choice) that paralleled the smaller consumption of tankage.

Probably these small differences in composition of the rations fed to the different lots did not actually affect the performance of the pigs.

Results.—Stiffness, even more severe than in the preceding test, developed in the pigs that were fed hulled oats and supplement. The

*The pigs in Lot 4 were given shelled corn, hulled oats, protein supplement, and mineral supplement free-choice during the last three weeks of the test.

TABLE 20.—VALUE OF OAT KERNELS^a WHEN FED AS DIFFERENT PROPORTIONS OF THE RATIONS OF GROWING-FATTENING PIGS: SIXTH TEST(Test began November 24, 1933, with 20 pigs to the lot.^b The rations^c were mixed and self-fed)

	Lot 1 Ground corn Supplement ^d	Lot 2 Ground corn 2 Hulled oats 1 Supplement ^d	Lot 3 Ground corn 1 Hulled oats 2 Supplement ^d	Lot 4 Hulled oats Supplement ^d
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>
Average initial weight.....	66	66	67	67
Average final weight.....	197	198	193	184
Average daily gain.....	1.26	1.45	1.39*	1.09
Average daily ration				
Cracked corn.....	4.65	3.50	1.74	.19
Hulled oats.....	.....	1.71	3.39	4.18
Protein supplement.....	.87	.76	.56	.29
Mineral supplement.....	.01	.02	.03	.04
Total.....	5.53	5.99	5.72	4.70
Feed for 100 lbs. gain				
Cracked corn.....	370	241	125	18
Hulled oats.....	.....	118	244	382
Protein supplement.....	68	53	40	27
Mineral supplement.....	1	2	2	3
Total.....	439	414	411	430
Composition of ration ^f	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>
Dry substance.....	88.75	88.87	89.24	89.37
Protein.....	14.66	15.04	15.50	15.27
N-free extract.....	62.52	61.94	61.52	61.64
Fiber.....	3.74	3.75	3.71	3.89
Ether extract.....	4.51	5.05	5.66	6.13
Ash.....	3.54	3.33	3.09	2.68

^aThe oat kernels fed in this test were in the form of hulled oats. They weighed 44 pounds a bushel and contained 4 percent of unhulled oats and free oat hulls.^bOne pig in Lot 3 and two in Lot 4 became unthrifty and were removed from the test. Beginning with the tenth week, a number of the pigs of Lot 4 became distinctly "crampy." Six of them became very lame. This trouble did not appear in the other lots.^cThe corn fed in this test averaged No. 4 grade, tho a little No. 3 and No. 5 was fed.^dAlfalfa meal, tankage, and minerals. The protein supplement included the 5 percent of alfalfa meal that was in all the rations *plus* whatever amount of tankage that was needed to equalize the protein content of the rations.^eFor the pigs that finished.^fComputed from analyses shown in Tables 26 and 27, Appendix.

stiffness became noticeable when the pigs had been on feed about seventy days, and by the end of the twelfth week five were in rather serious condition. A sixth died three weeks before the test closed. Stiffness did not develop in any other of the lots, altho three pigs in Lot 1, one in Lot 3, and one in Lot 4, failed to gain from the start and were removed early in the test.

Because of the severe stiffness of so many pigs in Lot 4 and none in the other lots, the Lot 4 pigs during the last three weeks were given access to shelled corn, hulled oats, and supplement (tankage, soybean oil meal, and alfalfa meal in the ratio 2:1:1) in separate compartments of the self-feeder, the mineral being continued as before. The pigs ate rather freely of the supplement during this time—to the extent of 7 percent of the ration—altho they ate only one-third as much corn

as hulled oats. Since no improvement in the condition of the five stiff pigs was observable during these three weeks, the lot was discontinued before the pigs reached a weight of 200 pounds. A preliminary study^a of the calcium and phosphorus relations in the blood of these pigs, and the reaction of the pigs to added minerals, cod-liver oil, or green forage indicated that this condition of stiffness was due to a disturbed calcium-phosphorus utilization. Stiffness was studied further in the test conducted in 1934-35.

Mixtures of corn and hulled oats were more palatable than either grain alone, if this can be judged by daily feed consumption (Table 20). During the entire test more of the ration containing corn and supplement than of the ration of hulled oats and supplement was consumed, altho the consumption of oats remained higher than of corn until the end of the sixth week of the test. The mixture made up of 2 parts corn and 1 part hulled oats was eaten more freely than was the mixture that contained more hulled oats, except during one period about midway in the test. The consumption of minerals increased with the proportion of oats in the ration. The pigs that received no corn ate minerals to the extent of .7 percent of the ration.

The rate of gain made by the pigs over the entire period of the test, and likewise, with minor exceptions, during the biweekly periods during the test, was in the same order as the rate of feed consumption—as might be expected. The pigs of Lot 4 led all others in gain during the first three biweekly periods, but during the fourth period their gain dropped to half the former rate and remained extremely low for the remainder of the test. The differences in average daily gain were statistically significant only between Lots 2 and 4, and 3 and 4.

Differences in amounts of the four rations eaten per hundredweight of gain were most likely without statistical importance. In Lot 2, 100 pounds of hulled oats saved 109 pounds of corn and 13 pounds of supplement, a figure that agrees closely with the results obtained the preceding year. In Lot 3, where a higher proportion of oats was fed, 100 pounds saved only 100 pounds of corn and 12 pounds of supplement, on the average, an amount lower than in the preceding year. The figure for Lot 4 was low, no doubt because of the unthriftiness of the pigs.

1934-35 test. The test of hulled oats during the winter of 1934-35 was made primarily to study the effects of different supplements in the hulled-oats rations on the development of stiffness in pigs (see following section, pages 156 to 162), but data on the value of oat

^aThis portion of this study was made by W. P. Garrigus.

kernels in the rations also were gathered. Contrary to earlier procedure only 10 pigs were fed in each lot in this test.

Five lots of 10 fall pigs each were fed the rations listed below. The pigs were housed in a central swine barn with concrete floors, each group of 10 pigs having access to a 10-by-16-foot space. The pigs were not permitted to go outside the barn at any time during the test (also contrary to previous practice), and all doors near the pens were kept closed. The only sunlight that reached the pens came thru small windows in the roof of the barn, and these were equipped with extra-heavy rough glass.

Rations.—Feed mixtures that contained 16 to 17 percent protein were prepared and were self-fed until the pigs reached weights of approximately 120 pounds each. The protein content was then reduced to 15 or 16 percent by replacing 2 pounds of tankage in 100 pounds of the mixture with an equal weight of grain. The tankage was thus eliminated entirely from all except the mixture for Lot 1. The beginning rations were:

<i>Feeds</i>	<i>Lot 1</i> <i>perct.</i>	<i>Lot 2</i> <i>perct.</i>	<i>Lot 3</i> <i>perct.</i>	<i>Lot 4</i> <i>perct.</i>	<i>Lot 5</i> <i>perct.</i>
Ground corn.....	82.5	.....	.....	.....	.....
Hulled oats, rolled.....	.....	92.5	91.0	91.5	90.0
Tankage.....	12.0	2.0	2.0	2.0	2.0
Alfalfa meal.....	5.0	5.0	5.0	5.0	5.0
Salt.....	.5	.5	.5	.5	.5
Bone meal.....	.....	.....	1.5	.....	1.5
Cod-liver oil.....	.....	.....	.....	1.0	1.0

Water was available to the pigs at all times.

Results.—The pigs suffered a mild attack of influenza during the first two weeks of the test, but recovered rapidly, except for one pig in Lot 5 that was replaced at the end of the third week.

From the standpoint of rate of gain, the addition of 1.5 percent of bone meal to the hulled-oats ration (Lot 3) made it just as effective as the check ration of corn and supplement (Table 21). Each 100 pounds of the basal ration plus bone meal produced as much gain as 122 pounds of the check ration. When both bone meal and cod-liver oil were included (Lot 5), the gain was slightly, tho not significantly, increased; and 100 pounds of the hulled-oats ration thus supplemented was as effective in producing gain as 125 pounds of the corn-and-supplement ration. The deficiencies of the basal ration alone (Lot 2) and of the basal ration plus cod-liver oil (Lot 4) were reflected in slower gains and higher feed requirements.

In computing from the results of this test the value of oat kernels in terms of corn, it seems only fair to exclude the results of Lots

TABLE 21.—BONE MEAL AND COD-LIVER OIL FOR CORRECTING MINERAL AND VITAMIN DEFICIENCIES OF HULLED OATS FOR GROWING-FATTENING PIGS
(Test started December 7, 1934, with 10 pigs to the lot)

	Lot 1 Corn, tankage, alfalfa meal, salt	Lot 2	Lot 3	Lot 4	Lot 5
		Basal ration* of hulled oats, tankage, alfalfa meal, and salt			
		Basal ration only	Bone meal	Cod-liver oil	Bone meal and cod-liver oil
Number of pigs to finish.....	10	8 ^b	10	10 ^c	10
Number of "stiff" pigs.....	(d)	10	1 ^e	4 ^f	1
Average initial weight.....	67	67	68	67	67
Average final weight.....	206	137	196	180	200
Average daily gain.....	1.24	.67	1.23	.95	1.36
Average daily ration					
Grain.....	4.68	3.20	4.20	4.14	4.50
Tankage, alfalfa.....	.88	.21	.27	.26	.29
Other ingredients.....	.03	.02	.09	.06	.15
Total.....	5.59	3.43	4.56	4.46	4.94
Feed for 100 pounds gain					
Grain.....	378	476	342	434	331
Tankage, alfalfa.....	72	33	22	27	21
Bone meal.....	.....	.....	5	.....	5
Cod-liver oil.....	.....	.....	.....	5	4
Salt.....	2	2	2	2	2
Total.....	452	511	371	468	363

*The corn fed in this test was No. 2 and No. 3 yellow; the tankage was of standard 60-percent grade; and the alfalfa meal was prepared by grinding a good quality of alfalfa hay. The hulled oats weighed 44 pounds a bushel and contained 91 percent of hulled kernels and 9 percent of small, unhulled oats and oat hulls. Only the hulled oats were analyzed chemically. They contained .054 percent of calcium and .425 percent of phosphorus. The other nutrients are reported in Table 26.

^bDiscontinued because of death losses and crippled pigs.

^cDiscontinued because of three crippled pigs and four others making poor gains.

^dTwo pigs were slightly lame two weeks before the lot finished but they recovered.

^eOne other pig became lame but recovered.

^fThree other pigs developed a "goose step" walk with rear legs.

2 and 4. When certain of the nutritive deficiencies of oat kernels were corrected by the addition of bone meal, as in Lot 3, 100 pounds of oats apparently replaced 111 pounds of corn and 13 pounds of supplement. The use of cod-liver oil in addition to bone meal apparently did not further improve the ration materially, since 100 pounds of oat kernels thus supplemented replaced only 114 pounds of corn and 13 pounds of supplement.

These values for hulled oats agree essentially with the values derived from the two preceding tests, 1932-33 and 1933-34, and also with the earlier tests with hulled oats (page 145).

Stiffness in Pigs Fed Hulled-Oats Rations

In cooperation with the division of Animal Nutrition of the Department of Animal Husbandry, the pigs of the 1934-35 test that were fed the rations discussed in the foregoing section were carefully observed, and tests were made of the blood and bones of the pigs to discover the

causes and corrective measures for the stiffness that develops in pigs that are fed rations composed chiefly of hulled oats.

External symptoms of stiffness. The pigs that were fed the check ration showed no typical symptoms of stiffness (as was the case in the two preceding tests), whereas those that were fed hulled oats and supplement without bone meal developed definite symptoms. By the end of the tenth week eight of the ten pigs in Lot 2 were definitely stiff, four of them severely so. One of these stiff pigs died during the eleventh week. By the end of the fourteenth week one more pig had died and another was sacrificed because of its extreme condition. On the head of the femur from each of these latter pigs was an eroded area about one-fourth by one-half inch in size. By this time (fourteenth week) four of the remaining pigs of Lot 2 were badly crippled and the others were either losing weight or gaining very slowly. Lot 2 was therefore discontinued and the four pigs that were most severely crippled were slaughtered. Bone meal and cod-liver oil were introduced into the ration of the three remaining pigs of this lot, two of which had not yet developed severe symptoms. But after 48 days on this ration containing bone meal and cod-liver oil two of the pigs were not yet back to normal, tho blood analyses indicated that the calcium and phosphorus contents of their blood had reached normal levels (Table 22). Post-mortem examination of all pigs that died or were slaughtered revealed evidence of faulty bone formations in all.

Two pigs of Lot 3, fed hulled oats and a supplement containing bone meal, showed slight lameness by the end of the twelfth week. One of these recovered and the other was still stiff when the lot finished at the end of fifteen weeks.

As a preventive of stiffness cod-liver oil proved to be a less valuable supplement to the basal ration than bone meal. One of the pigs that were fed the ration containing cod-liver oil (Lot 4) developed severe stiffness by the end of the tenth week. Two other pigs later became severely lame, and four others were stiff but less severely affected. A decline in the rate of gain of the pigs of this lot appeared in the fifth biweekly period of the test and became very marked as the test continued, until during the fifteenth and sixteenth weeks the average daily gain of the ten pigs was only .53 pound. During the seventeenth week the ten pigs lost a total of 20 pounds and a fourth pig became practically crippled. The lot was thereupon discontinued. The decline in gain was common to all the pigs of Lot 4, but was most marked with those most severely affected with stiffness.

TABLE 22.—CALCIUM AND INORGANIC PHOSPHORUS IN THE BLOOD SERUM OF PIGS FED HULLED-OATS RATIONS
(Milligrams per cubic centimeter.* Experimental feeding began December 7, 1934)

Date sampled	Lot 1			Lot 2			Lot 3			Lot 4			Lot 5		
	Number of pigs sampled	Ca	P	Number of pigs sampled	Ca	P	Number of pigs sampled	Ca	P	Number of pigs sampled	Ca	P	Number of pigs sampled	Ca	P
1934															
Dec. 27.....	3	mgss. 11.24	mgss. 8.69	3	mgss. 9.72	mgss. 8.91	3	mgss. 10.73	mgss. 9.26	3	mgss. 10.78	mgss. 8.98	3	mgss. 11.50	mgss. 9.52
1935															
Feb. 21.....	2	11.76	7.85	5	7.26	8.75	1	11.08	....	1	10.29	....	1	11.19	....
Mar. 13.....	1	11.97	8.68	9	7.29	8.78	1	11.13	8.57	1	10.34	11.08	1	12.55	11.86
Mar. 14.....	..	....	....	..	....	....	..	....	....	..	....	....	10	12.30	9.77
Mar. 25.....	..	....	....	..	....	....	10	11.36	10.71	..	....	....	..	....	....
Apr. 1.....	10	12.38	9.33	..	....	....	..	....	....	..	....	....	..	....	....
Apr. 3.....	..	....	....	..	....	....	..	....	....	10	8.91	9.07	..	....	....
Apr. 30.....	..	....	....	3	10.81	8.40	..	....	....	7	9.60	10.59	..	....	....
May 13.....	..	....	....	..	....	....	..	....	....	7	9.77	10.73	..	....	....

*Determinations made by the division of Animal Nutrition of the Department of Animal Husbandry. The calcium was determined by the Clark and Collip modification of the Kramer-Tisdall method. The method of Youngsberg and Youngsberg was used to determine inorganic phosphorus.

When Lot 4 was discontinued from the test proper at the end of the seventeenth week, the three badly crippled pigs were removed for slaughter. To the ration of the remaining seven, three of which were slightly lame and one rather severely so, was added sufficient trisodium phosphate to provide as much phosphorus as is carried by 1.5 pounds of bone meal. No further symptoms developed in any of the pigs, and after two weeks on the new ration the pig that was most severely affected was much improved. The blood calcium of the pigs rose slowly, but was still below normal when the observations were discontinued after 41 days. The concentration of inorganic phosphorus in the blood serum increased during the treatment to a level distinctly above normal (Table 21).

Each of the three pigs of this lot that were slaughtered at the end of the seventeenth week had one femur bone fractured. Two of the fractures were old and had healed, but the third was fresh, as tho it had been made during the trip to the abattoir. Typical beading of the ribs and some rib fractures, and congested lymph glands and enlarged kidneys, also were observed in the carcasses of these pigs.

The addition of both bone meal (1.5 percent) and cod-liver oil (1 percent) apparently corrected the mineral and vitamin deficiencies of the oats ration, inasmuch as the pigs of Lot 5 reached an average weight of 200 pounds in 98 days without loss. One pig showed a slight stiffness after ten weeks, and remained somewhat lame to the end of the test.

Calcium and inorganic phosphorus in blood serum. Quantitative determinations of the inorganic phosphorus and calcium in the blood serum of representative pigs in this test were made periodically.^a The bones of some of the pigs were likewise submitted to chemical analysis (see page 160).

The changes in the calcium and inorganic-phosphorus contents of the blood serum of these pigs as the test progressed are shown in Table 22. Thruout the test these elements remained at essentially normal levels in the pigs of Lots 1, 3, and 5. These were the lots that showed few abnormal external symptoms that could be attributed to the rations fed.

The shortage of calcium in the hulled-oats ration fed to the pigs of Lot 2 was reflected in the first blood test made, when the pigs had been on the experimental rations only 20 days. The second test, made

^aThe blood tests were made by F. I. Nakamura under the direction of T. S. Hamilton, division of Animal Nutrition, Department of Animal Husbandry. The bone analyses likewise were made by the Animal Nutrition division.

56 days later, at which time a number of pigs in Lot 2 had developed symptoms of stiffness, showed that the blood calcium had reached the very low level of 7.26 milligrams per cubic centimeter of blood serum. This low level continued as long as the pigs remained on this ration. The inorganic phosphorus in the blood remained at essentially normal levels thruout the test.

The use of cod-liver oil with the hulled-oats rations, even without additional minerals, sustained the calcium level (except for an initial decline) for 96 days (Lot 4, Table 22). Twenty-one days later, however, a level considerably below normal had been reached. Even tho the calcium content of the blood serum held up for 96 days, the rate of gain of these pigs began to decline markedly within 60 days after the pigs went on feed and became more unsatisfactory as the test continued. Lameness in the pigs began to appear about the 70th day.

The addition of trisodium phosphate, mentioned on the preceding page, to the ration of these pigs (Lot 4) brought about a slow rise in blood calcium and increased the inorganic phosphorus to a level above normal. The initial lameness of one pig thus fed improved materially, and no further lameness developed in any of the pigs during the 41 days that this treatment was continued.

Chemical analyses of bones. Pigs that developed typical symptoms of stiffness and became badly crippled were slaughtered and a femur and a scapula bone of each were taken for chemical study. Bones were also taken from three pigs of Lot 2 that had developed stiffness and had thereafter been fed for 48 days a ration that contained both bone meal and cod-liver oil. A femur and a scapula from one pig in Lot 3 (bone meal) that had shown no symptoms of stiffness were likewise analyzed. The data on bone analyses are given in Table 23.

Stiffness did not affect the composition of the bones as greatly as it did the composition of the blood or the appearance of the live pig, tho the bones of the one normal pig (12-39S CW) contained somewhat more total dry substance, ash, calcium, and phosphorus, than did the bones of the pigs unprotected by adequate supplements. Supplementing the ration with bone meal and cod-liver oil for 48 days, as was done with three lame pigs of Lot 2, produced bones that for the most part contained more total ash, calcium, and phosphorus than the bones of the untreated pigs contained, tho in most cases less than is found in normal bones.

TABLE 23.—COMPOSITION OF BONES OF PIGS THAT HAD DEVELOPED STIFFNESS WHEN FED RATIONS CONSISTING CHIEFLY OF HULLED OATS
(Test began December 7, 1934)

No. and sex of pig	Breed	Lot No.	Initial weight	Days on test	Final age	Slaughter weight	Percentages, on fresh basis ^a					Percentages, on water- and fat-free basis		
							Dry matter	Ether extract	Ash	Ca	P	Ash	Ca	P
Femurs														
4-9S.....	PC	2	60	95	190	81 ^b	46.3	7.8	19.0	6.8	3.0	49.3	17.8	7.8
4-90B.....	PC	2	56	98	193	99 ^c	48.4	12.1	16.5	5.9	2.6	45.5	16.2	7.3
3-30B.....	PC	2	68	102	207	132	46.3	10.1	16.9	6.2	2.7	46.8	17.3	7.6
91-3B.....	PC	2	74	102	202	118	49.0	12.0	16.6	6.2	2.8	45.1	16.7	7.7
26-30S.....	PC	2	67	102	206	117	47.8	11.1	17.4	6.3	2.8	47.3	17.2	7.7
19-30B.....	PC	2	67	102	204	103	48.2	10.7	16.9	6.1	2.9	45.2	16.3	7.7
3-9B.....	PC	4	63	123	228	132	62.1	25.2	19.4	7.2	3.5	52.5	19.6	9.6
91-9S.....	PC	4	59	123	223	143	54.9	19.6	18.7	6.9	3.4	51.5	19.1	9.3
2-93S.....	CW	4	76	123	229	155	56.5	22.2	18.0	6.6	3.2	52.5	19.4	9.3
12-39S.....	CW	3	73	109	224	245 ^d	64.0	20.2	25.0	9.5	4.2	57.1	21.6	9.7
Scapulas														
4-9S.....	PC	2	60	95	190	81 ^b	40.5	1.5	16.8	6.0	2.6	43.0	15.3	6.8
4-90B.....	PC	2	56	98	193	99 ^c	38.4	3.2	13.3	4.7	2.2	37.7	13.3	6.1
3-30B.....	PC	2	68	102	207	132	42.8	5.8	15.2	5.4	2.4	40.9	14.6	6.9
91-3B.....	PC	2	74	102	202	118	41.2	4.5	14.3	5.4	2.5	39.0	14.6	6.9
26-30S.....	PC	2	67	102	206	117	41.2	3.8	16.1	5.7	2.9	43.2	15.2	7.8
19-30B.....	PC	2	67	102	204	103	48.5	4.2	17.8	6.4	3.1	40.1	14.5	7.0
3-9B.....	PC	4	63	123	228	132	54.6	12.5	20.5	7.6	3.8	48.7	18.1	8.9
91-9S.....	PC	4	59	123	223	143	49.1	10.3	17.6	6.4	3.2	45.2	16.6	8.3
2-93S.....	CW	4	76	123	229	155	49.6	12.2	17.2	6.2	3.1	45.9	16.7	8.3
49-90B.....	CW	2	73	157	271	180 ^e	65.0	26.1	19.7	7.3	3.6	50.6	18.8	9.2
2-90S.....	CW	2	71	157	263	275 ^e	78.8	18.4	32.1	11.9	5.9	53.1	19.6	9.8
49-93S.....	CW	2	77	157	271	160 ^e	52.9	13.2	18.4	7.0	3.3	46.5	17.6	8.3
12-39S.....	CW	3	73	109	224	245 ^d	55.3	9.4	23.5	8.6	4.0	51.2	18.9	8.8

^aAs in original bones.^bTwenty-six days earlier this pig weighed 114 pounds.^cFourteen days earlier this pig weighed 109 pounds.^dHad not been stiff.^eFor 48 days prior to slaughter this pig had been fed the ration of Lot 5, containing both bone meal and cod-liver oil.

General Analysis of Data on Value of Oat Kernels

The wide variation in the values for oat kernels obtained in the seven tests just discussed makes the assigning of a definite value to the oat kernels rather hazardous. The variation did not appear to be associated with the quality of the corn fed, the proportion of oats in the ration, or the form in which the oat kernels were fed, whether "steel-cut," hulled, or hull-less, unless it were a slight advantage for the "steel-cut oats." In order, therefore, to give such an assigned value the weight of all experimental evidence possible, the results from comparable lots of pigs that were fed oat kernels in the same test have been averaged^a and the averages placed in Table 24 along with the results from the check lots of the same tests.

A total of 130 pigs were fed the check ration without oats, while 320 pigs were fed oat kernels as a part of their rations. The pigs that received the oats rations gained on the average slightly faster and consumed somewhat less total feed for each unit of gain made than did their test mates that were fed only corn and supplement.

Since in each of these seven comparisons there is a result for the check ration and a corresponding one from the same experiment for the ration that contained oat kernels, the data are suitable for analysis by Student's method for paired comparisons.

In six of the seven comparisons the pigs on the oats rations gained more rapidly than the pigs on the check rations, the mean difference being + .079 pound. The standard deviation of this difference is .065 pound, and the probability that the difference was due to chance is only 1 in 77. In five of the seven comparisons somewhat less feed per unit of gain was eaten by the pigs that were fed the oats ration than by those that were fed the check ration. As an average of the seven comparisons this difference amounted to 36.3 pounds of feed. The standard deviation of this mean is 34 pounds, and the probability of such an outcome being due to chance is only 1 in 50.

The foregoing analysis indicates that oat kernels fed in these tests increased slightly both the rate and the economy of gain.

Differences of the order found in these experiments would shorten the feeding period of 50-pound pigs that are carried to a weight of 200 pounds by about 6 days and save approximately 8 percent of the total feed.

The average amounts of feed saved by each 100 pounds of oat kernels fed in these tests varied from 136 pounds of corn and 20

^aThe use of these averages seems warranted, since the average daily gains of the pigs did not differ significantly from lot to lot.

TABLE 24.—VALUE OF OAT KERNELS IN THE RATIOMS OF GROWING-FATTENING PIGS: SUMMARY OF THE SIX TESTS
(Averages of comparable data in Tables 15 to 20 inclusive. All weights expressed in pounds)

	1926		1927		1929-30		1930-31		1932-33		1933-34		1934-35		Average	
	Check	Steel-cut oats	Check	Hulled oats	Check	Hull-less oats	Check	Hull-less oats	Check	Hulled oats	Check	Hulled oats	Check	Hulled oats	Check	Oat kernels
Number of pigs.....	20	80	20	60	20	60	20	20	20	40 ^b	20	40 ^b	10	20 ^c	130	320
Number of pigs to finish.....	20	78	18	53	20	60	18	19	19	39	20	39	10	20	125	308
Average initial weight.....	52	52	68	68	77	77	69	68	71	71	66	66	67	68	67	67
Average final weight.....	202	200	195	203	197	199	198	204	201	200	197	196	206	198	199	200
Average daily gain ^a	1.32	1.35	1.24	1.35	1.55	1.59	1.23	1.21	1.24	1.41	1.26	1.42	1.24	1.30	1.30	1.38
Average daily ration.....	4.98	2.54	4.46	3.79	6.27	3.81	4.77	3.92	4.38	2.48	4.65	2.62	4.68	.....	4.88	2.74
Oat kernels.....	1.88	1.88	.....	1.34	.....	2.22	.....	1.30	.....	2.55	.....	2.55	.....	4.35	.....	2.31
Supplement.....	77	41	81	59	80	57	72	49	1.09	.84	88	.88	.91	40	85	5.37
Total.....	5.75	4.83	5.27	5.72	7.07	6.60	5.49	5.80	5.47	5.80	5.53	5.85	5.59	4.75	5.74	5.62
Feed for 100 pounds gain.....	379	189	361	285	404	240	407	325	361	176	370	183	378	.....	380	200
Ground corn.....	.....	140	.....	100	.....	140	.....	115	.....	176	.....	181	.....	337	.....	170
Oat kernels.....	58	30	65	45	52	36	62	40	90	60	69	48	74	30	67	41
Supplement.....	437	359	426	430	456	416	469	480	451	412	439	412	452	367	447	411
Feed saved by 100 pounds hulled oats.....	.....	136	.....	76	.....	117	.....	71	.....	105	.....	103	.....	112	.....	106
Corn.....	.....	20	.....	20	.....	11	.....	19	.....	17	.....	12	.....	13	.....	15
Supplement.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

^aFor the pigs that finished.

^bOne additional lot in this test was fed only hulled oats and supplement, but because of the development of stiffness in the pigs the results are not included in this average.

^cAmong the pigs of two additional lots in this test stiffness developed so severely that the pigs did not reach market weight. Results from these lots are not included in this average.

pounds of supplement in the 1926 test to 71 pounds of corn and 19 pounds of supplement in the 1931-32 test. In two of the tests the oat kernels apparently saved even less than their own weight of other feed. As an average of these averages (last column) 100 pounds of oat kernels saved 106 pounds of corn and 15 pounds of protein supplement. The values indicated by the seventeen individual lots upon which this table is based are fairly well grouped around this mean. In only three lots was the saving below 110 pounds of total feed, and in only four lots (all in the same test) was the value above 135 pounds. The amount of supplement saved by each 100 pounds of hulled oats fell between 10 and 20 pounds in thirteen of the seventeen lots.

For practical purposes, of course, the unhulled oats from which the hulled oats are derived must be considered in comparisons of this kind. If the recovery of hulled oats is 67 percent, as it was with the most efficient machine used in these tests, 149 pounds of oats in the hull would be required to provide 100 pounds of hulled oats. Each 100 pounds of oats in the hull, therefore, when hulled and fed in these tests, replaced 71 pounds of corn and 10 pounds of protein supplement. One hundred pounds of ground oats in this same study, however, replaced 85 pounds of corn and 8 pounds of supplement (Table 12).

These two methods of preparing oats (grinding and hulling) for use as part of the ration of growing-fattening pigs were compared directly in three of the early tests. The average data from comparable lots in these tests are given in Table 25. In the individual tests the differences in rate of gain made by the pigs fed the two rations were

TABLE 25.—COMPARISON OF GROUND OATS AND OAT KERNELS FED IN THE SAME TESTS: AVERAGE OF THREE TRIALS
(All weights expressed in pounds)

	Ration containing ground oats	Ration containing oat kernels
Number of pigs.....	100	160
Number of pigs to finish.....	99	150
Average initial weight.....	62	62
Average final weight.....	199	202
Average daily gain.....	1.25	1.30
Average daily ration		
Corn.....	3.66	3.41
Oats.....	1.32	1.54
Supplement.....	.58	.50
Total.....	5.56	5.45
Feed for 100 pounds gain		
Corn.....	292	267
Oats.....	107	118
Supplement.....	45	38
Total.....	444	423

not significant, and the differences in amounts of feed eaten per unit of gain made are within the range of variation to be expected in such work.

In terms of feed replacement, 100 pounds of oat kernels (149 pounds unhulled oats) saved 112 pounds of grain (corn and ground oats) and 6 pounds of supplement. Or 100 pounds of oats in the hull saved, when fed as hulled oats, only 75 pounds of grain and 4 pounds of supplement. These totals are remarkably close to those arrived at in the discussion of the average data given in Table 24, page 163.

Thus the evidence from both the direct comparison of hulling and grinding oats (Table 25) and the indirect comparison (Table 24) indicates rather definitely that grinding oats is a more profitable preparation than hulling when the oats are to be fed as a part of the ration of growing-fattening pigs thruout the feeding period.

Tests With Oat Kernels at Other Stations

The few drylot feeding trials with oat kernels that have been conducted at other stations are in substantial agreement with the work reported here. For example, Robison^{11, 12, 19*} found that oat kernels fed as part of the grain allowance replaced approximately the same amount of other feed per unit as they did when they were fed as the only grain. And in two tests at the Ohio Station^{14, 16*} in which hulled oats and hull-less oats were compared directly, the two appeared to be of approximately equal value.

Two tests have been reported from the Ohio Station^{12, 16*} and one from Indiana^{23*} in which grinding and hulling were compared as methods of preparing oats for growing-fattening pigs. The difference in rate of gain made by the pigs fed the two rations was probably not statistically significant in any of the tests. In all three comparisons, however, the difference in rate of gain was in favor of the hulled-oats ration, as was also the difference in total feed eaten for each unit of gain made. On the average, 100 pounds of ground oats in these three tests saved 89 pounds of corn and 8 pounds of supplement, a value very near that found in the Illinois tests. The feed-replacing value of 100 pounds of hulled oats fed in these tests varied, however, from 92 to 197 pounds of feed, whereas the average replacement by hulled oats in the seven Illinois tests was 121 pounds.

GENERAL SUMMARY AND CONCLUSIONS

Prior to the time when the tests reported in this bulletin were begun very little experimental work had been done on the value of oats in the ration of growing-fattening swine. In these experiments, covering the ten-year period from 1926 to 1936 and including also the results of some early feeding trials made at this Station from 1917 to 1919, seventeen different feeding trials were made involving 1,290 pigs. Particular attention has been given to the effect of increasing the proportion of oats in the ration, the value of grinding oats, and the value of hulling oats.

The significant facts brought out by the study, and the conclusions drawn from them are:

1. *Oats may be fed to growing-fattening swine to the extent of nearly half the ration without appreciably decreasing the rate of gain of the pigs.* The average daily gains of pigs fed rations containing from no oats at all to one-half oats (ground), were: no oats in the ration, 1.46 pounds; one-third oats, 1.44 pounds; and one-half oats, 1.38 pounds (Table 5). In the tests in which whole oats were fed, the pigs that were fed a ration consisting of one-third oats gained 1.18 pounds a day each, as an average, whereas the pigs that received only oats and supplement gained only .74 pound per head daily (Table 6).

2. *Including oats in any proportion in the ration of fattening pigs increases slightly the total amount of feed required for each unit of gain made.* In one series of tests in which the rations consisted of various proportions of cracked corn, ground oats, and supplement, the average total amounts of feed required per hundredweight of gain were: no oats in the ration, 418 pounds; one-third oats, 426 pounds; and one-half oats, 450 pounds (Table 5).

3. *The replacement value of ground oats was higher than of whole oats,* as judged by the amount of other feed saved when oats were introduced into the ration. The replacement value of whole oats averaged 59 pounds of corn and 7 pounds of supplement per 100 pounds of oats, whereas the ground oats replaced, on an average, 85 pounds of corn and 8 pounds of supplement (Table 12). If supplement is valued at three times the cost of grain, the whole oats would thus be 75 to 85 percent as valuable as corn, and the ground oats would be 90 to 110 percent as valuable as corn. There was some indication that as the proportion either of whole oats or of ground oats in the ration increased, their value decreased. *Unless oats are as cheap per pound as corn, or cheaper, they probably cannot be used profitably in the ration of fattening pigs.*

4. *Grinding oats increased their value as a feed for growing-fattening pigs.* When oats made up about one-third of the ration, there was an average saving of 26 pounds of corn and 1 pound of supplement directly traceable to the grinding of 100 pounds of oats (Table 12).

5. *The palatability of oats for pigs is increased by any method of preparation that makes the hulls less noticeable.* The palatability of the oats was measured by the proportions of oats and of corn that were consumed by the pigs when the two feeds were offered free-choice. These proportions were: 8 percent oats when the oats were whole, 23 percent when they were coarse ground, 42 percent when fine ground, and 63 percent when they were hulled.

6. *Oat kernels were more valuable pound for pound than corn in these tests.* On the average, 100 pounds of oat kernels equaled the combined value of 106 pounds of corn and 15 pounds of protein supplement (Table 24). The proportion of oat kernels in the ration appeared not to influence the value of the oat kernels.

7. *Hulling oats proved to be a less profitable method of preparing them for pigs than grinding.* This is true despite the fact that the hulled oats were somewhat more palatable to the pigs than the ground oats. The kernels obtained from hulling 100 pounds of oats (67 pounds of kernels, by the most efficient machine used) replaced only 71 pounds of corn and 10 pounds of supplement, whereas 100 pounds of oats that were ground replaced 85 pounds of corn and 8 pounds of supplement.

Whether or not hulling oats to feed to growing-fattening swine will be profitable in any given case will depend on the cost of hulling, the efficiency of the machine used, and the value and cost of other methods of preparing oats for feed. The charge for hulling oats is usually higher than for grinding, and the most efficient hulling machine used in these tests recovered only 88 percent of the oat kernels that were put into it. From 4 to 9 percent of the amount recovered was unhulled oats and free oat hulls. The hulled oats recovered weighed 67 percent of the weight of the original oats put into the machine.

8. *Rations of hulled oats supplemented by 5 percent of alfalfa meal induced a condition of stiffness and unthriftiness in pigs fed in drylot that often terminated in the death of the pigs.* The calcium content of the blood was depressed, but there was little change in the inorganic-phosphorus content. Bone fractures and beading of the ribs were observed in all the affected pigs. The stiffness was prevented by the incorporation of 1.5 percent of bone meal in the ration or, somewhat better, by a combination of bone meal and cod-liver oil. Cod-liver oil without the bone meal did not prevent the stiffness.

LITERATURE CITED

1. CARROLL, W. E. Oats as a feed for swine. Ill. Agr. Exp. Sta. Circ. 414. 1933.
2. EASTWOOD, G. R. Substitutes for corn in rations for fattening pigs. Ohio Agr. Exp. Sta. Bul. 268. 1914.
3. EVVARD, J. M., *et al.* The utilization of oats in the growing and fattening of spring pigs. *And* Corn belt rations for fattening spring pigs on pasture and in dry lot. Iowa Agr. Exp. Sta. Leaflet 19. 1926.
4. FERRIN, E. F., and MCCARTY, M. A. What should be the proportion of corn to oats in rations for growing pigs? Minn. Agr. Exp. Sta. mimeo. rpt. H-30. 1927.
5. ———— Corn compared with barley and mixtures of barley and oats. Minn. Agr. Exp. Sta. mimeo. rpt. H-34. 1928.
6. ———— *et al.* A comparison of five grains as hog feeds. Minn. Agr. Exp. Sta. mimeo. rpt. H-48. 1931.
7. HENRY, W. A. Whole oats versus ground oats for hogs. *In* Wis. Agr. Exp. Sta. Ann. Rpt. 6 (1889), pp. 20-23.
8. NORTON, L. J., and WILSON, B. B. Prices of Illinois farm products from 1866 to 1929. Ill. Agr. Exp. Sta. Bul. 351. 1930.
9. PETERS, W. H., *et al.* Five grains as hog feeds. Minn. Agr. Exp. Sta. mimeo. rpt. H-46. 1930.
10. Preliminary report on comparison of feeds for fattening hogs. *In* Okla. Agr. Exp. Sta. Ann. Rpt. 28 (1919), pp. 27-33.
11. ROBISON, W. L. Oats as a feed for hogs. *In* Ohio livestock days. Ohio Agr. Exp. Sta. 1927.
12. ———— Ohio Agr. Exp. Sta. Circ. 10. 1928.
13. ———— Swine feeding experiments with fall pigs. Ohio Agr. Exp. Sta. Spec. Circ. 17. 1929.
14. ———— Swine feeding experiments. Ohio Agr. Exp. Sta. Spec. Circ. 32. 1931.
15. ———— Improving corn and tankage for pigs not on pasture. Ohio Agr. Exp. Sta. Bul. 488. 1931.
16. ———— Swine feeding experiments, 1931. Ohio Agr. Exp. Sta. Spec. Circ. 39. 1932.
17. ———— Letter to authors. Apr. 8, 1932.
18. ———— Letter to authors. Aug. 24, 1932.
19. ———— Letter to authors. Mar. 12, 1935.
20. THOMPSON, C. P. Swine feeding investigations. *In* Okla. Agr. Exp. Sta. Bul. 148. p. 4. 1923.
21. VESTAL, C. M. The value of grinding oats for hogs. Purdue Univ. Agr. Exp. Sta. mimeo. rpt. Oct. 20, 1928.
22. ———— Different proportions of corn and oats for fattening hogs. Purdue Univ. Agr. Exp. Sta. mimeo. rpt. Jan. 15, 1929.
23. ———— Grinding or hulling oats for hogs. Purdue Univ. Agr. Exp. Sta. mimeo. rpt. Oct. 20, 1930.

APPENDIX

TABLE 26.—COMPOSITION OF GRAIN FEEDS USED IN THE EXPERIMENTS^a

Feed, and date test began	Tables Nos.	Percent kernel	Weight per bushel	Commercial grades	Percentage composition					
					Dry matter	Protein	N-free extract	Crude fiber	Ether extract	Ash
<i>Corn</i>	9, 14 12-17-27.....	.....	.....	Nos. 4 and 5	81.27	7.50	68.26	1.84	2.59	1.08
	3, 10 7-13-29.....	.....	.....	2 and 3	86.24	8.00	69.63	3.72	3.60	1.29
	3, 17 1-25-30.....	.....	.....	4, 5, 6	81.32	7.88	67.32	2.41	2.48	1.23
	4 7-15-30.....	.....	.....	2, 3	88.42	8.72	71.61	3.12	3.70	1.27
	18 1-22-31.....	.....	.....	3, 4	86.08	9.50	69.42	1.83	4.21	1.12
	11 6-17-31.....	.....	.....	2, 3, 4, 6	86.22	8.81	70.04	2.43	3.62	1.32
	11 12-25-31.....	.....	.....	2, 3	86.31	8.75	69.90	2.23	4.27	1.16
	20 11-24-33.....	.....	.....	3, 4, 5	88.49	8.88	71.68	2.84	3.80	1.29
<i>Oats</i>	7 6-12-26.....	.....	34	.....	90.07	.....	.....	12.12	.....	.....
	13 2-5-27.....	.....	.....	.....	93.72	11.75	.....	12.40	.....	.....
	2 6-25-27.....	67	31	.....	89.32	10.63	57.95	11.57	4.50	4.67
	9, 14 (Lot 2) 12-17-27.....	67	27	.....	89.06	9.63	58.11	12.36	4.68	4.28
	9, 14 (Lot 4) 12-17-27.....	67	27	.....	87.55	9.56	56.42	12.51	4.72	4.34
	14 (Lot 3) 12-17-27.....	71	31	.....	89.83	11.06	58.37	12.48	4.32	3.60
	3, 10 ^a 7-13-29.....	71	31	.....	89.59	10.44	58.83	12.34	4.35	3.63
	8-3-29.....	71	33	.....	89.96	11.56	59.19	10.34	5.37	3.50
	4 7-15-30.....	71	33	.....	89.61	11.88	61.31	9.54	3.35	3.53
	18 1-22-31.....	71	34	.....	89.57	10.94	58.58	11.03	5.30	3.72
	11 6-17-31.....	71	.....	.....	89.31	12.50	57.98	10.31	5.05	3.47
<i>Hulled oats</i>	11 12-25-31.....	75	34	.....	.....	.....	.....	.....	.....	.....
	15 7-24-26.....	87 ^d	.....	.....	93.09	15.31	.....	5.38	.....	.....
	16 6-25-27.....	81 ^d	.....	.....	89.76	16.06	63.30	2.32	6.10	1.98
	19 12-9-32.....	96 ^d	46	.....	90.03	15.19	63.70	2.67	6.41	2.06
	20 11-24-33.....	92 ^d	44	.....	88.22	16.15	61.15	2.65	6.06	2.19 ^e
	21 12-7-34.....	91 ^d	44	.....	.....	.....	.....	.....	.....	.....
<i>Hull-less oats</i>	17 1-25-30.....	80 ^f	45	.....	87.95	14.81	64.42	2.72	3.74	2.26
	18 1-22-31.....	96 ^f	52	.....	92.11	16.06	67.06	2.40	4.57	2.02

^aAll analyses were made by the Animal Nutrition division of the Department of Animal Husbandry. Unfortunately not all the feeds were analyzed, and in some tests only the feed mixtures were analyzed. Inconsistencies in the chemical data for the 1934-35 tests (Table 21) threw some doubt on their accuracy and they are not reported. After this became known there was still available a sample of the hulled oats, which were analyzed and the analyses reported.

^bAverage grade was No. 3.

^cOats as fed to Lots 2, 3, and 4, Table 3, and Lot 3, Table 10.

^dRemainder was unhulled oats and free oat hulls.

^eThese hulled oats contained .054 percent Ca and .425 percent P.

^fRemainder was regular oats in the hull.

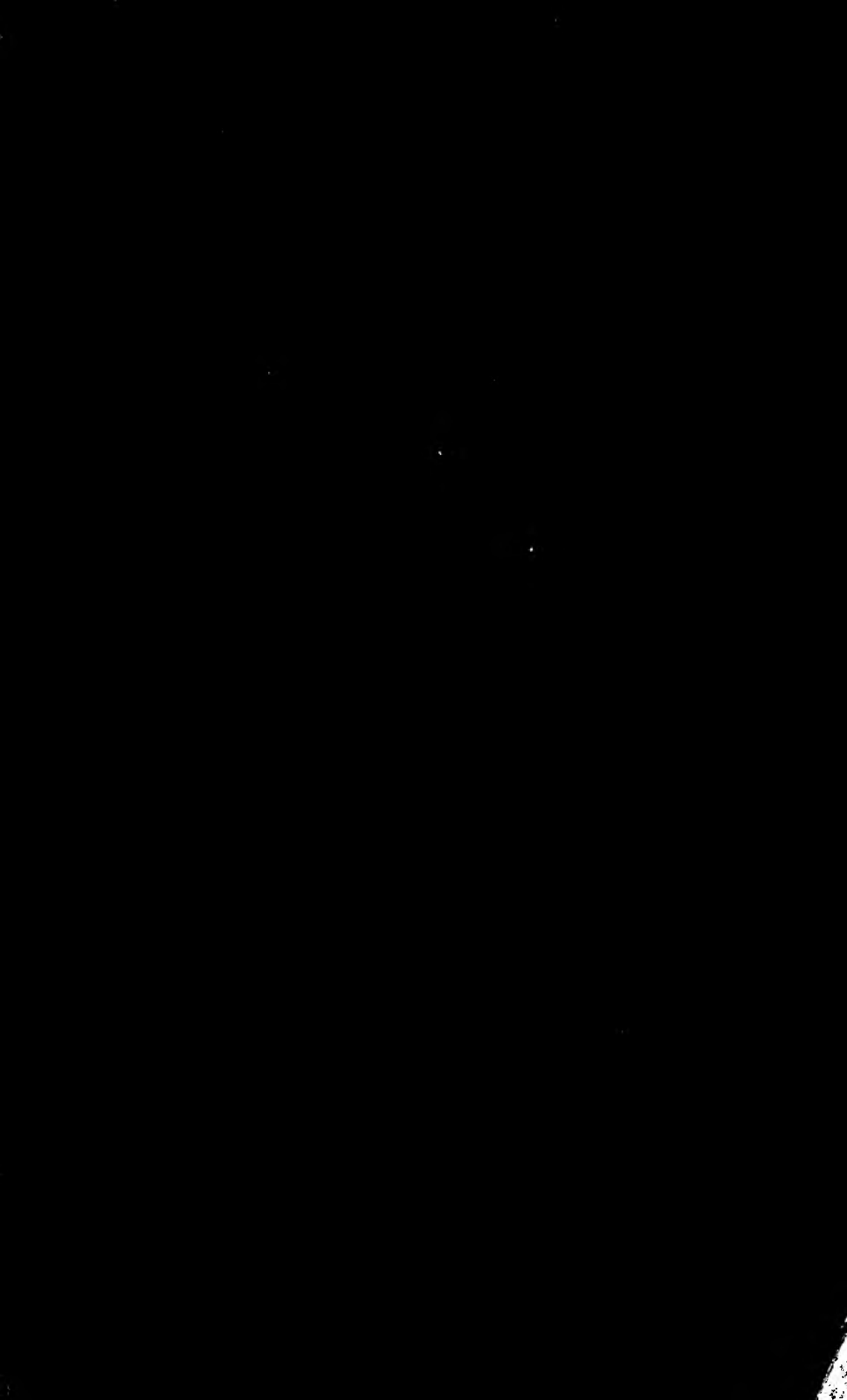
TABLE 27.—COMPOSITION OF PROTEIN SUPPLEMENTS USED IN THE EXPERIMENTS*

Feed, and date test began	Table Nos.	Dry matter	Protein	N-free extract	Crude fiber	Ether extract	Ash
		<i>perct.</i>	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>
<i>Tankage</i>							
12-17-27.....	9, 14	93.00	56.38	3.88	1.63	12.49	18.62
7-13-29.....	3, 10	92.39	56.25	2.71	1.44	11.05	20.94
1-25-30.....	17	91.81	61.00	1.86	1.57	6.78	20.60
7-15-30.....	4	94.58	54.62	.94	1.29	12.15	25.58
1-22-31.....	18	92.56	53.75	.98	.69	15.91	21.23
6-17-31.....	11	93.26	63.06	.....	3.25	9.77	19.26
12-25-31.....	11	93.01	62.50	.....	3.26	8.79	20.13
11-24-33.....	20	92.01	60.13	2.77	.94	10.69	17.48
<i>Linseed meal</i>							
12-17-27.....	9, 14	89.60	32.56	35.85	8.91	6.63	5.65
7-13-29.....	3, 10	89.73	32.25	31.26	11.10	7.41	7.71
1-25-30.....	17	89.11	35.50	33.31	9.40	5.41	5.49
7-15-30.....	4	90.15	36.12	32.35	9.67	6.80	5.21
1-22-31.....	18	91.95	35.81	34.81	9.86	6.34	5.13
6-17-31.....	11	90.82	38.75	31.29	9.10	6.19	5.49
12-25-31.....	11	90.72	38.31	33.38	8.43	5.41	5.19
<i>Alfalfa meal</i>							
12-17-27.....	9, 14	86.49	16.00	38.00	21.87	2.75	7.87
7-13-29.....	3, 10	89.56	17.56	36.34	25.47	1.85	8.34
1-25-30.....	17	88.13	16.94	35.44	24.36	2.19	9.20
7-15-30.....	4	91.08	17.00	38.74	23.59	1.92	9.83
1-22-31.....	18	90.72	18.25	41.32	16.33	3.10	11.72
6-17-31.....	11	89.26	19.12	37.34	17.12	3.27	12.41
12-25-31.....	11	89.41	18.88	31.33	17.19	2.77	19.24
11-24-33.....	20	90.36	17.56	36.32	24.91	3.70	7.87

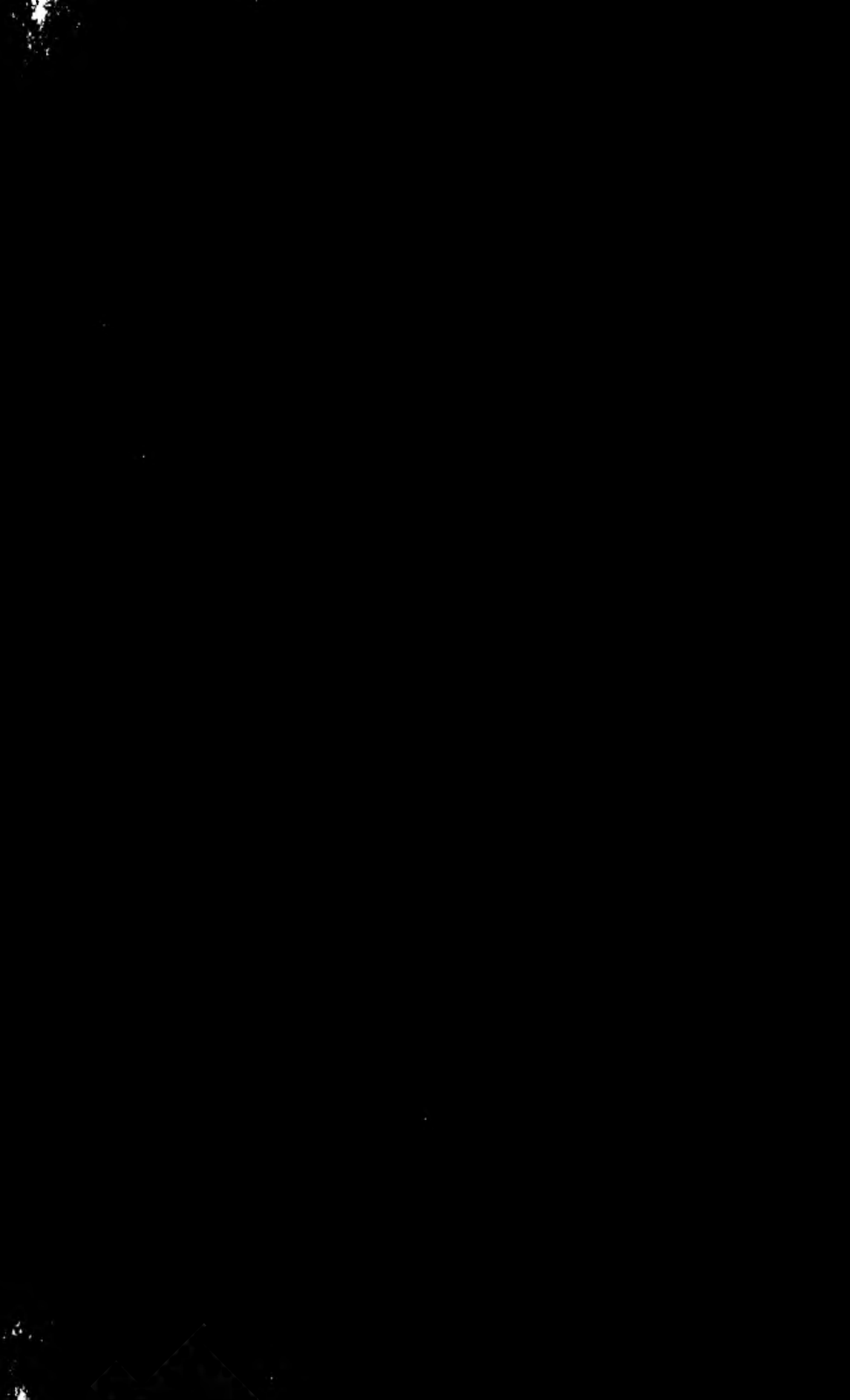
*All analyses were made by the Animal Nutrition division of the Department of Animal Husbandry. Unfortunately not all the feeds were analyzed, and in some tests only the feed mixtures were analyzed.

LIST OF TABLES

	PAGE
1. Comparison of whole and ground oats in the rations of swine: Early Wisconsin tests	116
2. Proportions of whole and of ground oats in the rations of growing-fattening pigs: First test.....	122
3. <i>Same</i> , Second test.....	123
4. <i>Same</i> , Third test	124
5. <i>Same</i> , Summary of the three tests.....	125
6. Whole oats as a substitute for corn in the rations of growing-fattening pigs: Summary of weights, gains, and feed consumption.....	128
7. Value of grinding oats for growing-fattening pigs; First test.....	130
8. <i>Same</i> , Second test.....	131
9. <i>Same</i> , Third test.....	132
10. <i>Same</i> , Fourth test.....	134
11. <i>Same</i> , Fifth and sixth tests.....	135
12. <i>Same</i> , Summary of the six tests.....	136
13. Coarse or fine grinding of oats for growing-fattening pigs: First test...	139
14. <i>Same</i> , Second test.....	140
15. Value of oat kernels when fed as different proportions of the rations of growing-fattening pigs: First test.....	144
16. <i>Same</i> , Second test.....	146
17. <i>Same</i> , Third test.....	147
18. <i>Same</i> , Fourth test.....	149
19. <i>Same</i> , Fifth test.....	151
20. <i>Same</i> , Sixth test.....	153
21. Bone meal and cod-liver oil for correcting mineral and vitamin deficiencies of hulled oats for growing-fattening pigs.....	156
22. Calcium and inorganic phosphorus in the blood serum of pigs fed hulled-oats rations.....	158
23. Composition of bones of pigs that had developed stiffness when fed rations consisting chiefly of hulled oats.....	161
24. Value of oat kernels in the rations of growing-fattening pigs: Summary of the six tests.....	163
25. Comparison of ground oats and oat kernels fed in the same tests: Average of three trials.....	164
26. Composition of grain feeds used in the experiments.....	169
27. Composition of protein supplements used in the experiments.....	170







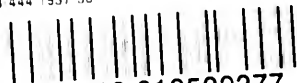
UNIVERSITY OF ILLINOIS-URBANA

Q 630 .7/L6B

C002

BULLETIN URBANA

433 .444 1937-38



3 0112 019529277