RESEARCH BULLETIN 626 APRIL, 1957

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

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Amino Acid Composition of Swine Rations and Amino Acid Requirements of Weanling Pigs

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(Publication authorized April 15, 1957)

COLUMBIA, MISSOURI

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This Bulletin Reports on Department of Animal Husbandry Research Project 141, "Swine Nutrients."

Amino Acid Composition of Swine Rations and Amino Acid Requirements of Weanling Pigs

W. H. PFANDER AND L. F. TRIBBLE

Until the early part of the 19th century, food and feedstuffs were considered as units. Few attempts were made to evaluate their efficiency in promoting life functions. Magendie (1816) recognized that the nitrogen-containing fractions of foods were important and showed (1841) that meat proteins were superior to gelatin. However, the idea that proteins were of equal nutritional value persisted until about 1900.

Kossel and Kutscher (1900) and Fischer (1901) showed that proteins could be broken down, quantitatively, into their constituent amino acids by chemical action. This gave biochemists reasonably adequate tools for their studies of protein composition. Cohnheim (1906) showed that an enzyme, erepsin, freed amino acids from proteins in animals at body temperatures. By 1904, 17 amino acids were known.

Osborn and Mendel isolated and tested the nutritional value of many plant proteins. In 1914, they showed that rats could maintain body weight on a zein ration supplemented with tryptophan but needed extra lysine before they could grow. Subsequent research (1924) showed that many plant proteins were improved by the addition of amino acids, usually lysine or tryptophan. The cereal proteins were especially deficient in lysine.

However, it was not possible to raise rats with amino acids as the only source of nitrogen until Rose's laboratory isolated threonine (McCoy *et al.* 1935). Rose and co-workers then determined the essential amino acids (1938) and the quantitative requirements (1948) for the growing rat. Other investigators used other species for similar studies. The results have been reviewed by Almquist (1952, 1954) and Rose (1952). Rats (Rose and Rice, 1939), chicks (Almquist 1952), pigs (Shelton *et al.,* 1950) and dogs (Silber *et al.,* 1949) made adequate growth when amino acid mixtures were used to supply the nitrogen in their diets.

Thus, research has established that protein nutrition in the monogastric animal is essentially amino acid nutrition. Many investigators now report the amino acids present in ration ingredients and are interested in determining the amino acid requirements of different classes of animals. When sufficient evidence has accumulated, it should be possible to evaluate the adequacy of a ration by calculating its amino acid content and comparing it to the requirement of the animal for which it was balanced.

The amino acid requirements for swine have been summarized by the National Research Council (1953) and Almquist (1954). They are based primarily on results of tests made by supplementing rations that were low in some amino acid with various amounts of the amino acid under test. Since the summaries were compiled, requirement figures for valine (Jackson *et al.,* 1953) and leucine (Eggert *et al.,* 1954) have been published.

Most common feedstuffs have been analyzed for the essential amino acids. Extensive studies are now under way to determine the variations caused by variety and environment.

The National Research Council lists requirements for lysine, methionine and tryptophan that are greater than the amounts present in common swine ration ingredients.

This bulletin reports on tests conducted to determine if amino acid fortification would improve practical swine rations, and if proteins known to be adequate for rats are also adequate for swine. On the basis of these experiments, it appears that: (1) small advantages may be obtained by supplementing some practical rations with lysine, methionine or tryptophan; (2) the amino acid requirements of swine should be expressed as a percent of protein of the ration; (3) the requirements of the National Research Council for lysine, methionine and tryptophan are adequate to meet the growth needs of young swine; and (4) pigs weighing more than 75 pounds have much lower requirements than younger pigs.

REVIEW OF LITERATURE

Estimated Requirements of Swine

The National Research Council (1953) has summarized the literature on amino acid requirements based on nitrogen retention, the gain of pigs, and feed efficiency. Since this publication appeared, additional estimates of amino acid requirements have been obtained (Jackson *et al.,* 1953; Eggert *et al.,* 1954). Almquist (1954) has re-evaluated the requirements on the basis of log plots.

Curtin *et al.,* (1952a) and Williams *et al.* (1954) have analyzed the carcasses of swine for the essential amino acids and calculated the ratios between the content of lysine and each of the other essential amino acids. By multiplying the ratio between lysine content and the content of each of the other essential amino acids in the tissues by the previously determined lysine requirement, they estimated the requirement for the other essential amino acids. The validity of this method is limited by the accuracy of determination of the lysine requirement and by the fact that the amino acids are not equally well digested, absorbed and retained. It is known that tryptophan can serve as a precursor of niacin (Luecke, 1947; 1948; Powick, 1948) and that methionine serves a number of metabolic functions (du Vigneaud *et al.,* 1941). Denton and Elvehjem (1954 a and b) found amino acids were not absorbed at the same rate and Schweigert (1947a) and Suberlich *et al.,* (1948) found they were not excreted at the same rate.

Estimates of amino acid requirements can be obtained by determining or calculating the amino acid content of rations which have given satisfactory growth and have not responded to supplementation of the essential amino acids. Responses have not been as great as expected from supplementation of practical rations which appeared low in one or more essential amino acid on the basis of NRC requirements. Using growth rate and feed efficiency as criteria, responses to lysine have been obtained by adding 0.1 percent to rations containing 12 percent of crude protein from corn and soybean meal (Catron, 1953; Pond, 1953) and to others containing 14 percent crude protein from milo and soybean meal (Pond, 1953). Responses also have been obtained by adding 0.15 percent to a mixed ration (Pfander and Tribble, 1953); 0.4 percent DL-lysine to a corn-cottonseed meal ration (Dyer, 1952); and 0.1 - 0.3 percent DL-lysine to a corn-cottonseed-alfalfa meal-fish solubles ration (Miner *et al.,* 1955). No response was obtained when a 14 to 16 percent corn and soybean meal ration was supplemented with lysine (Catron, 1953; Meade, 1956).

Dyer *et al.* (1949) obtained a growth response when 0.2 percent of DL methionine was added to a 20 percent corn-soybean meal ration. No response was obtained by Ferrin (1946) with a 17 percent ration; by Catron (1953) with a 12, 14 or 16 percent ration; or by Pfander and Tribble (1953) with 16 and 18 percent rations. Curtin *et al.* (1952c) concluded that a purified ration containing 20 percent of soybean protein supplied adequate methionine.

Tryptophan supplementation improved a corn-meat and bone scraps ration (Bloss, 1953; Terrill *et al.,* 1954) and a corn-cottonseed meal-alfalfa meal ration (Miner *et al.,* 1955).

Becker *et al.* (1954) fed rations of corn, supplemented with fish meal or soybean meal, and determined the level of protein needed for optimum performance. They analyzed their rations for lysine, tryptophan and methionine and calculated the level of each present in the optimum ration. Their work indicated a lower requirement than had been indicated by tests using rations that were low in some particular amino acid or by using specially prepared feedstuffs. Later work (Becker *et al.,* 1955) indicated that these estimates were valid.

Figure 1—The essential amino acid spectrums of the proteins of corn, soybean meal and fish meal and the amino acid requirements of weanling pigs.

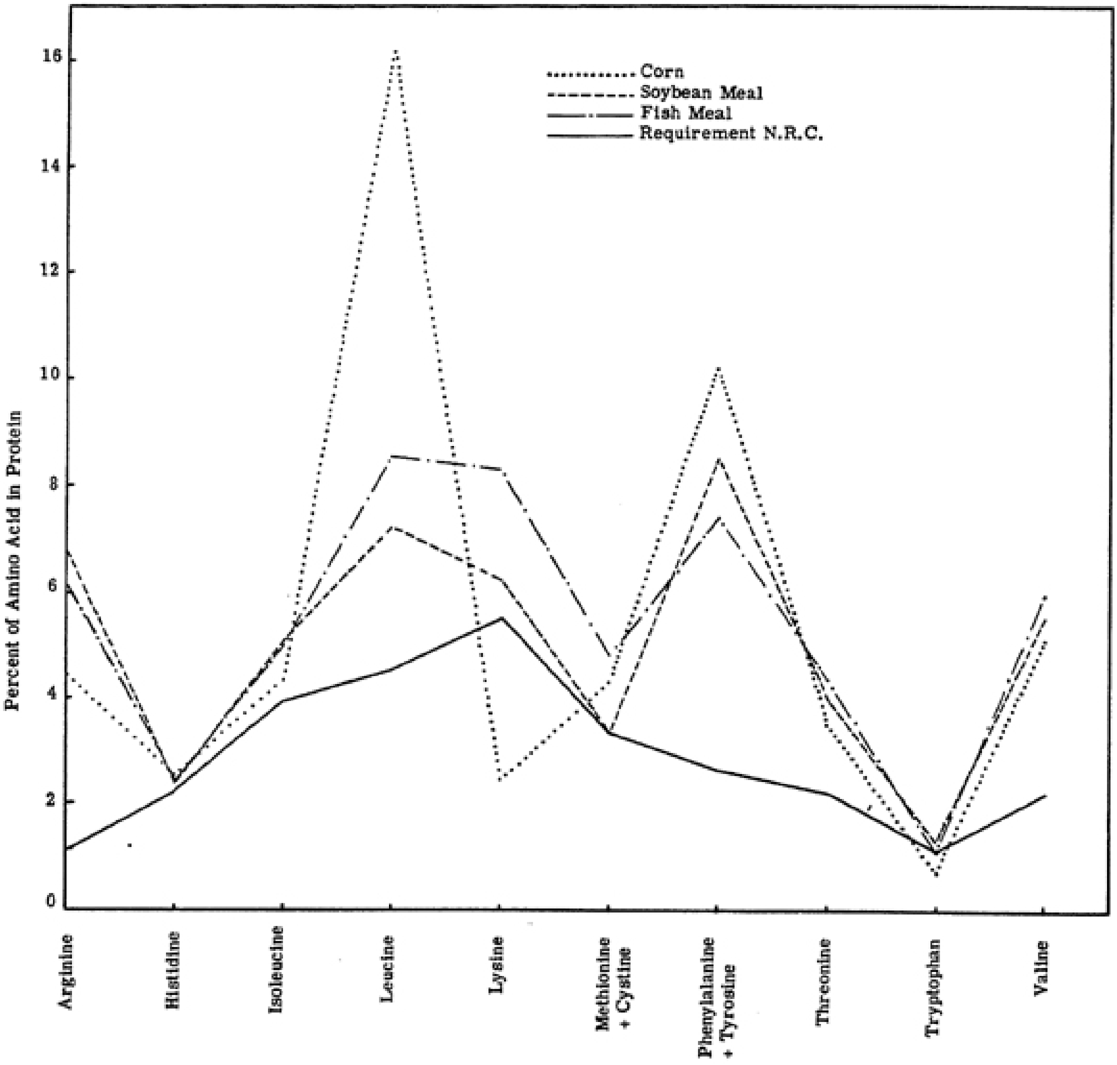


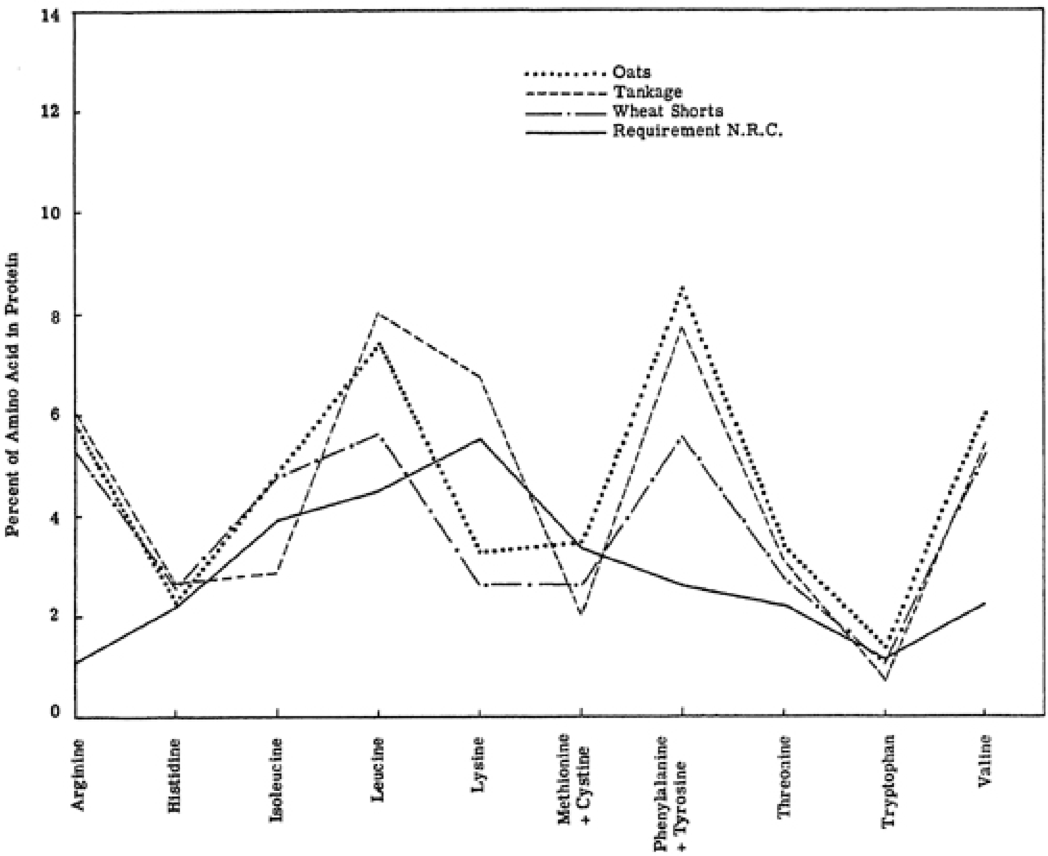
Table 1 *summarizes available estimates of the requirements for the essential amino acids.

The Amino Acid Composition of Feedstuffs

Numerous papers reporting the composition of one or more feedstuffs have been used in preparing our summary of feedstuff composition. The main sources of summarized information were Block and Mitchell (1947), Titus (1952), Almquist (1953), National Research Council (1953), and Fairbanks (1954). Values listed by all authors were tabulated and apparent duplications were excluded. To these values were added others which appeared to have been obtained with reliable methods. All values

*Tables 1 and 2 in Appendix, p. 36.

Figure 2—The essential amino acid spectrums of the proteins of oats, tankage and shorts and the amino acid requirements of weanling pigs.



were converted to a standard N x 6.25 basis and, where possible, standard deviations of the means were computed. These values are summarized in Table 2.

Amino acid spectrums of several swine feeds and the requirements of pigs were prepared after the method of Oser (1953). These are shown in Figures 1 through 4 and indicate that amino acid deficiencies occur in popular ingredients of swine rations as follows: lysine-alfalfa, barley, corn, oats, wheat and wheat shorts; sulfur amino acids-soybean meal (borderline), tankage and wheat shorts; tryptophan-corn, tankage, and wheat shorts (borderline); histidine-alfalfa and barley.

Figure 3—The essential amino acid spectrums of the proteins of barley, skim milk and alfalfa and the amino acid requirements of weanling pigs.

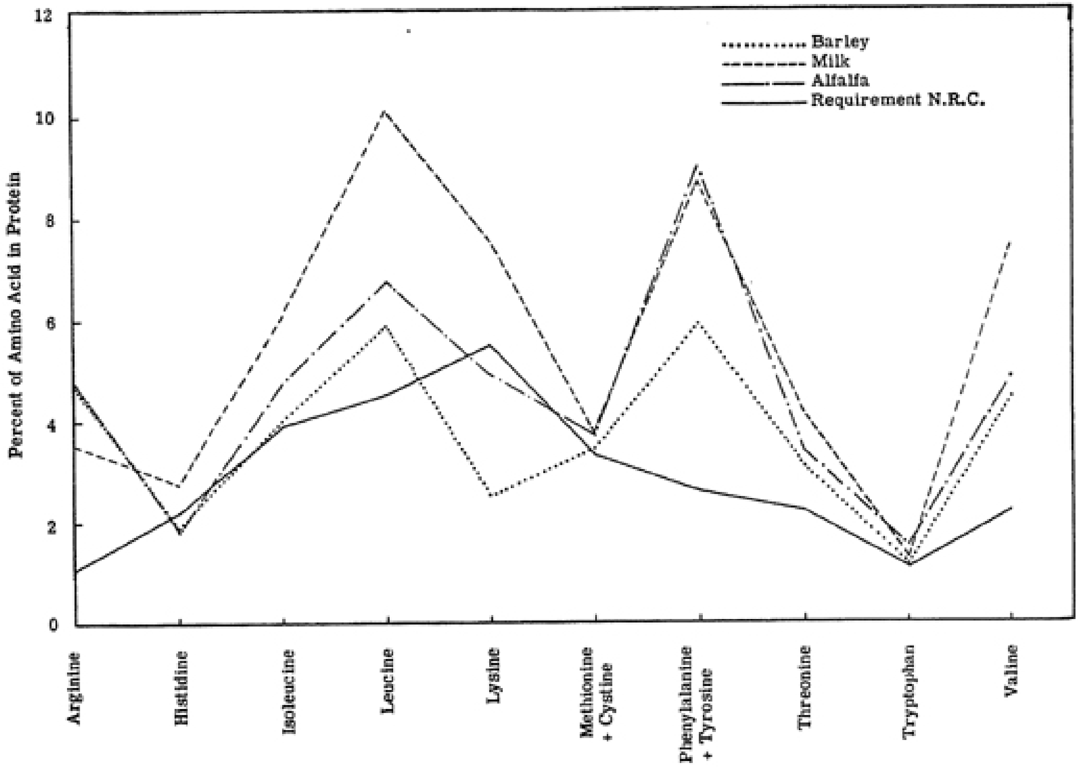
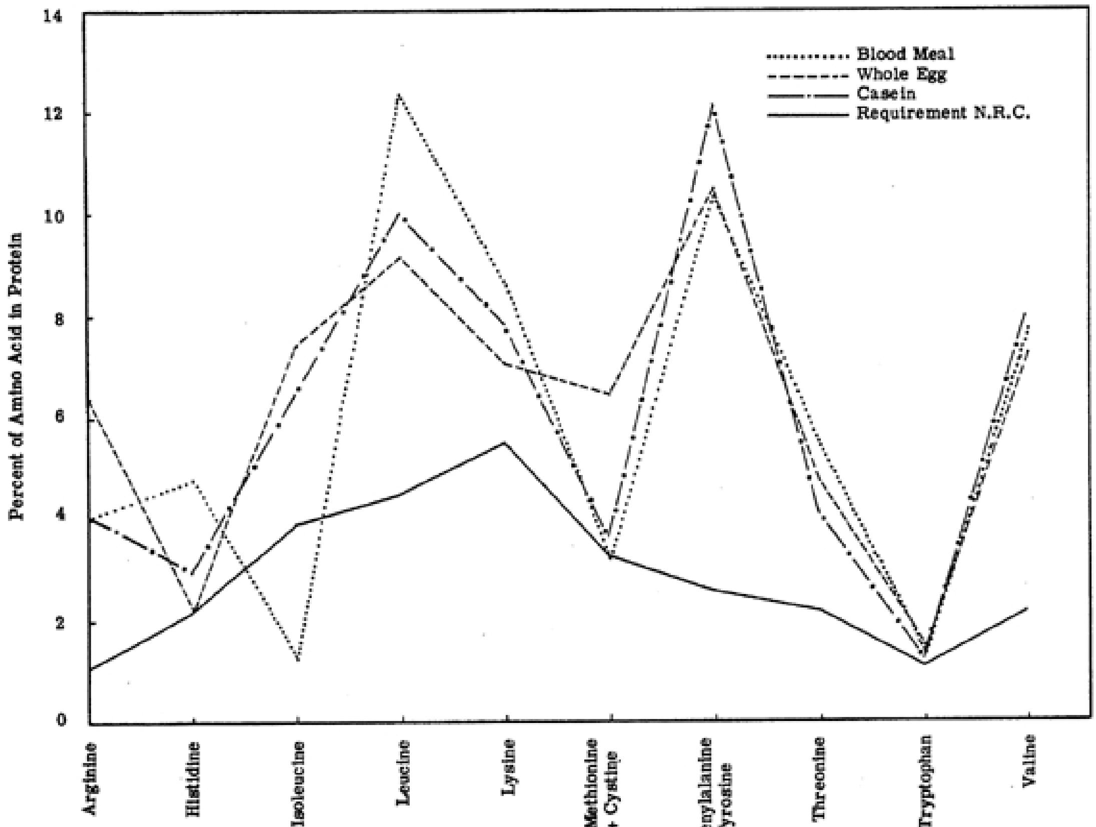


Figure 4—The essential amino acid spectrums of the proteins of blood meal, whole egg and casein and the amino acid requirements of weanling pigs.



METHODS

All but three experiments were conducted with Chester White pigs. In one experiment 20 Hampshire pigs were used, in another, 60 crossbred Landrace-Poland Chinas and in the third experiment, Hampshires and Durocs. After weaning at 56 days of age, the pigs were allocated to experimental lots and fed on concrete floored pens until they weighed approximately 100 pounds. In two experiments pigs were carried to about 200 pounds final weight. Pigs were weighed weekly and records of feed consumption were kept.

PRACTICAL RATIONS

Three experiments were conducted with two basal rations. Ration A was composed of corn and a supplement of 2 parts soybean meal, 2 of tankage, and 1 of wheat shorts. The ratio of corn and supplement was varied to obtain desired protein levels. Ration B was formulated from corn and soybean oil meal. The initial protein level was 18 percent in Experiment 1 and 16 percent in Experiments 2 and 3. When the pigs weighed approximately 75 pounds the level of protein was reduced to 16 percent in Experiment 1 and 14 percent in Experiment 2 and 3. Both rations were fortified with vitamins and minerals to reach the levels recommended by the National Research Council (1950). The compositions of the basal rations are shown in Table 3. Rations were self fed in Experiments 1 and 2 and were hand fed in Experiment 3.

TABLE 3 -- COMPOSITION OF THE BASAL RATIONS

	Ration A			Ration B		
	Percent	Crude	Protein	Percent	Crude	Protein
Components	18	16	14	18	16	14
Ground yellow corn 1/	742.5	787.5	839.5	727.5	761.5	817.5
Soybean oil meal, 44% solvent 2/	100	80	58	250	211	155
Tankage, 60% 2/	100	80	58	---	---	---
Wheat gray shorts	50	40	29	---	---	---
Vitamins 3/	1	1	1	1	1	1
Choline chloride, 25% dry mix	0.5	0.5	0.5	0.5	0.5	0.5
Limestone	---	5.0	8.0	12.5	12.0	9.0
Salt	5	5.0	5.0	5.0	5.0	5.0
Bonemeal	---	---	---	2.5	8.0	11.0
Antibiotic 4/	+	+	+	+	+	+

1/ Amount of corn varied slightly, depending on the antibiotic used. Sufficient corn was added to make 1000 lb. of ration.

2/ Blended from at least two sources.

3/ Each lb. contained 7 gm. nicotinic acid, 7 gm. pantothenic acid, 1 gm. riboflavin, 4 mg. vitamin B_{12}, 976,500 I.U. vitamin A and 173,600 I.U. vitamin D.

4/ One lb. TM 10 in experiment 1, 6 lb. Aureofac in experiment 2 and 3 lb. of Aureofac 2A in experiment 3.

Litters of pigs were allocated to the experimental treatments according to the 6 x 6 or 7 x 7 Latin square design.

Experiment 1 (1953 Spring Farrow)

Six litters of six pigs were allocated to the following six lots: Lot 1, basal A; Lot 2, basal A + 0.15 percent L-lysine; Lot 3, same at Lot 2 + 0.04 percent DL-methionine; Lot 4, basal B; Lot 5, basal B + 0.15 percent L-lysine; Lot 6, same as 5 + 0.04 percent DL-methionine.

Experiment 2 (1953 Fall Farrow)

Seven litters of seven pigs were allocated to seven lots: Lot 1, basal A; Lot 2, basal A + 0.1 percent L-lysine; Lot 3, basal A + 0.04 percent DL-methionine; Lot 4, same as 2 + 0.04 percent DL-methionine; Lot 5, basal B; Lot 6, basal B + 0.1 percent L-lysine; Lot 7, basal B + 0.04 percent methionine.

Experiment 3 (1954 Spring Farrow)

The treatments were:

Lot	1	Basal A-antibiotic	
	2	"	+ 0.1 percent L-lysine + 0.4 percent DL-methionine + 0.04 percent DL-tryptophan
	3	"	
	4	"	+ L-lysine + DL-tryptophan
	5	"	+ L-lysine
	6	"	+ DL-lysine + DL-methionine
	7	"	+ L-lysine-antibiotic
	8	"	+ DL-tryptophan
	9	"	+ DL-methionine
	10	"	+ DL-tryptophan + DL-methionine

A 6 x 6 Latin square design was used to allot pigs to lots 2-7. Lots 1 and 8-10 contained six pigs similar to those in lots 2-7.

Experiment 4 (1954 Spring Farrow)

This experiment was designed to test the value of supplementing a corn and shorts ration with small amounts of amino acids. Chester White pigs were allotted to the test at weaning. Lot 1 received an excellent mixed ration (formulated from corn, shorts, tankage, soybean meal, fish meal, alfalfa meal, minerals and vitamins). Lot 2 received the corn and shorts ration supplemented with 0.25 percent L-lysine hydrochloride, 0.06 percent DL-methionine and 0.04 percent DL-tryptophan. Table 4 lists the rations.

TABLE 4 -- THE COMPOSITION OF RATIONS TO TEST THE PERFORMANCE OF PIGS FED A CORN SHORTS RATION SUPPLEMENTED WITH AMINO ACIDS

Ration Ingredients	Weaning to 75 lbs.		75 lbs. to 200 lbs.	
	1	2	1	2
Ground yellow corn	776	423	829	658
Wheat Gray shorts	30	550	19	315
Tankage, 60% C. P. %	60	---	38	---
Soybean oil meal, Solvent 1/	60	---	38	---
Fish meal, 62.5% C. P.	30	---	30	---
Alfalfa meal	30	---	30	---
Vitamin premix 2/	1	1	1	1
Choline Chloride, 25%	0.5	0.5	---	---
Aureofac 2A	3	3	1.5	1.5
Limestone	5	18	8	16
Salt	5	5	5	5
Bonemeal	---	---	---	2
L lysine hydrochloride	---	2.5	---	2.5
DL methionine	---	0.6	---	.4
DL tryptophan	---	0.4	---	.4

1/ Blended from two sources

2/ Premix prepared from 35 gms. niacin, 35 gms. calcium pantothenate, 5 gms. riboflavin, 40 mgm. B_{12} and vitamin A and D (2250-400 drymix to 10 lbs.

TABLE 5 -- RATIONS USED TO TEST THE VALUE OF AMINO ACID SUPPLEMENTATION TO A CORN WHEAT SHORTS RATION FOR GROWING FATTENING SWINE

Ration	1		2		3	
Protein level	14%	12%	14%	12%	14%	12%
Ground Y. corn	423	658	423	659	424.5	660
Wheat G. shorts	548	314	550	315	550	315
Aureofac 2A	1.5	1.5	1.5	1.5	1.5	1.5
Vitamin premix	0.5	0.5	0.5	0.5	0.5	0.5
Choline chloride (25%)	0.5	---	0.5	---	0.5	---
Salt (trace mineralized)	5	5	5	5	5	5
Limestone	18	18	18	18	18	18
L-lysine HC1 92%	2.5	2.5	1.25	1.25	---	---
DL methionine	0.6	---	0.3	---	---	---
DL tryptophan	0.3	0.3	0.15	.15	---	---

14% crude protein rations until 75 lbs.
12% crude protein rations from 75-100 lbs.
All pigs received ration 3 containing 12 percent protein after they weighed 100 pounds.

Experiment 5 (1954 Fall Farrow)

Twenty-one unthrifty pigs, Durocs and Hampshires, were divided into three uniform lots and hand fed the rations shown in Table 5 until they weighed 200 pounds.

Experiment 6 (1954 Fall Farrow)

Sixty crossbred Landrace-Poland pigs were allotted to the following six treatments:

Lot 1 Basal + 0.04 percent DL-tryptophan
2 Basal + 0.05 percent L-lysine
3 Basal + 0.04 percent DL-tryptophan + 0.04 percent DL-methionine
7 Basal + 0.04 percent DL-methionine
5 Basal
6 Basal + lysine + methionine + tryptophan

Each lot contained five pigs and was replicated. Table 6 gives the compositions of the rations.

TABLE 6 -- COMPOSITION OF CORN AND TANKAGE RATIONS

	1	2	3	4	5	6
Ground yellow corn, lb	876.5	876	876	876.5	877	876
Tankage, 60%, lb	115	115	115	115	115	115
Salt, lb	5	5	5	5	5	5
Aureofac, 2A, lb	1.5	1.5	1.5	1.5	1.5	1.5
Choline chloride, 25%, lb	1.0	1.0	1.0	1.0	1.0	1.0
Vitamin mix *, lb	0.5	0.5	0.5	0.5	0.5	0.5
DL tryptophan, gm	182	---	182	---	---	182
L lysine, HCl, gm	---	300	---	---	---	300
DL methionine, gm	---	---	182	182	---	182

* Vitamin mix contained: Vitamin A and D (2250,400) 10 lbs., Riboflavin 10 gm., Niacin 10 gm., Vitamin B12 (0.1%) 25 gm., Calcium pantothenate 50 gm.

When the pigs reached an average weight of 75 lbs. the ration was changed to 912 lbs. corn, 76 lbs. tankage, 5 lbs. lime, 5 lbs. salt, 1.5 lbs. aureofac, 2A, and 0.5 lbs. vitamins. Lysine and tryptophan were added at the same rates as above, but the methionine was reduced to 91 gms. per 1000 lbs. ration.

Experiment 7 (Fall Farrow, 1954)

Twenty Hampshire pigs were divided equally into two lots. Lot 1 pigs had access to a self feeder containing shelled corn and a protein supplement of: tankage, 483; salt, 10; choline chloride, 2.5; Chlortetracycline supplement, 4;* and vitamin and trace mineral mix, 0.5. The ration for Lot 2 was identical, except that 2 pounds of tankage were replaced by 800 grams DL-tryptophan.

PURIFIED RATIONS

Several proteins were tested for their growth promoting value as single sources of protein in purified rations or when fed as supplements to corn.

*Contains 3.6 grams chlortetracycline per pound of supplement.

Experiment 8 (Fall Farrow, 1952)

Twenty-four Chester White pigs were allocated to eight lots of three and fed rations that supplied all of the protein as soybean oil meal, casein, or liver meal, or as combinations of two of these sources. The rations are shown in Table 7.

TABLE 7 -- THE COMPOSITION OF PURIFIED RATIONS

Ration Ingredients	1	2	3	4	5	6	7	8
Soybean meal	41	--	--	13.5	14	--	--	41
Casein	--	20	--	13.5	--	10.5	10.5	--
Liver residue	--	--	21.5	--	14	10.5	10.5	--
Antibiotic	--	--	--	--	--	--	+	+

In addition each ration contained: Woodpulp 3, minerals 5, cod liver oil 0.5, soybean oil 3.0, starch to 100.

And the following vitamins in mg. per lb. of feed: Thiamine 2, riboflavin 2.5, niacin 15, calcium pantothenate 4.5, pyridoxine 2.5, choline chloride 450, inositol 250, vitamin B_{12} 0.01, folic acid 0.25, biotin 0.09, vitamin E 5, Vitamin K 5.

Experiment 9 (Fall Farrow, 1953)

Three lots of three pigs were fed rations containing 12 percent crude protein. Ration 1 contained dried whole egg and corn; ration 2, whole egg and corn plus 0.2 percent L-lysine and 0.05 percent tryptophan; and ration 3 was a purified ration, similar to those used in trial 8, containing 12 percent of whole egg protein. Table 8 gives the compositions of the rations.

TABLE 8 -- THE COMPOSITION OF RATIONS CONTAINING WHOLE EGG

Ration	1	2	3
Whole Egg	45	45	45
Corn starch	---	---	316
Ground corn	440	440	---
Aureofac	1.5	1.5	1.25
Stabilized A and D (2250-400)	0.5	0.5	0.5
Vitamin starch 1/	0.5	0.5	0.5
Salt	2.5	2.5	4.5
Steamed bonemeal	6	6	5.5
Ground limestone	5	5	3
L lysine, as monohydrochloride	---	1.25	---
DL tryptophan	---	0.25	---

1/ to supply the following vitamins, mg. per lb. total ration: calcium pantothenate 7, niacin 7, riboflavin 1, biotin .022, folic acid 0.15, pyridoxine 0.25, thiamine 0.5, vitamin B_{12} .004, para amino benzoir acid 1, choline 450, vitamin K 5, vitamin E 5.

Experiment 10 (Spring Farrow, 1954)

The experiment was designed to test: (1) The value of casein as a supplement to a corn ration; (2) the value of ration A supplemented with fish and alfalfa meal; (3) the value of a corn-shorts ration supplemented with arginine, lysine, tryptophan and methionine. Compositions of the rations are shown in Table 9. The pigs were similar to those in Experiment 3 and were fed at the same time.

TABLE 9 -- THE COMPOSITION OF RATIONS USED TO DETERMINE THE VALUE OF CORN-CASEIN AND CORN SHORTS RATIONS

	From Weaning to 75 lbs.				From 75 lbs. to 100 lbs.			
Ration Number	3	11	12	13	3	11	12	13
Ground yellow corn	786	776	870	423	837	829	900	668
Wheat grey shorts	40	30	---	550	29	19	---	315
Tankage	80	60	---	---	58	38	---	---
Soybean oil meal solvent	80	60	---	---	58	38	---	---
Fish meal	---	30	---	---	---	30	---	---
Alfalfa meal	---	30	---	---	---	30	---	---
Casein	---	---	100	---	---	---	70	---
Vitamin premix *	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Choline chloride, 25%	0.5	0.5	0.5	0.5	---	---	---	---
Chlortetracycline supplement **	3.0	3.0	3.0	3.0	1.5	1.5	1.5	1.5
Limestone	5.0	5.0	11.0	18.0	8.0	8.0	10.0	16.0
Salt	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Bonemeal	---	---	11.0	0	2.0	---	12.0	2.0
Arginine	---	---	---	0.7	---	---	---	---
L-lysine as hydrochloride	---	---	---	2.5	---	---	---	2.5
DL Methionine	---	---	0.4	0.6	---	---	0.4	0.4
DL-Tryptophan	---	---	---	0.4	---	---	---	0.4

* Vitamin premix prepared from 35 grams niacin, 35 grams calcium pantothenate, 5 grams riboflavin, 40 mg. vitamin B_{12} and vitamin A and D (2250-400), drymix to 10 lbs.

** Contains 3.6 grams of chlortetracycline per 1 lb. of supplement.

RESULTS AND DISCUSSION

Feed Consumption

Pigs that were fed during the fall and winter periods usually consumed more feed than similar pigs fed in the spring or summer. This is probably an expression of the need for additional calories for heat by the pigs fed during the cold weather.

There were, however, no significant differences in daily feed consumption of the pigs fed basal rations and those fed the supplemented rations. Pigs usually consumed more of ration A when it was supplemented with lysine or methionine and more of ration B when it was not supplemented. When both lysine and methionine were present, daily feed consumption was similar to that of the basal group. Pigs fed the purified ration at the 18 percent protein level consumed less feed than pigs in the other experiments, but there were no differences between groups. The feed consumption of the pigs fed the whole egg ration was relatively high; however, these pigs were on feed during very cold winter weather and all the pigs in the barn at that time had a high rate of feed consumption. Pigs that were fed the ration of corn and casein or the ration of corn and shorts supplemented with amino acid consumed less feed than those on more practical rations.

Growth

Practical Rations Containing Proteins of Good Quality

The average daily gains of the pigs are summarized in Tables 10 to 12. The lots receiving ration A supplemented with lysine always gained more than the lots receiving the basal ration. However, in each experiment, a pig in one or more litters grew faster on the basal ration than any of his litter mates did on the supplemented ration. In Table 13, the average daily gains of all pigs receiving the supplemented rations are compared to the mean gain of all pigs of the same sex within a litter. The difference between the basal group and the lysine-supplemented group was significant ($P < 0.05$). The difference between the basal group and the group receiving lysine and methionine supplements was not significant.

The response of the pigs to lysine in Experiment 3 was nearly as great from rations that did not contain an antibiotic (Lot 1 vs. Lot 7) as from those that did (Lot 3 vs. Lot 5). There was no evidence that aureomycin spared lysine.

Pigs receiving supplements of DL-methionine in Experiments 2 and 3 and DL-tryptophan, DL-tryptophan + L-lysine, and L-lysine + DL-tryptophan + DL-methionine in Experiment 3 grew at a faster rate than pigs on the basal rations.

TABLE 10 -- THE EFFECT ON GROWTH RATE AND FEED EFFICIENCY OF SUPPLEMENTING PRACTICAL SWINE RATIONS WITH L-LYSINE AND DL-METHIONINE

EXPERIMENT 1, SPRING 1953

Lot number	1	2	3	4	5	6
Ration	Basal A	A+L[1]	A+L[1]+M[2]	Basal B	B+L[1]	B+L[1]+M[2]
No. of pigs	6	6	6	6	6	6
Avg. initial wt., lb.	35.0	34.3	32.5	34.0	33.0	34.8
Avg. final wt., lb.	98.3	102.5	96.8	99.3	95.7	101.3
Avg. daily gain, lb.	1.29	1.39	1.29	1.34	1.24	1.36
Avg. daily feed, lb.	3.78	3.90	3.53	3.93	3.58	4.07
Feed/cwt. gain, lb.	293	280	274	294	289	300

1 0.15 percent of L-lysine was added as the hydrochloride.
2 0.04 percent of DL-methionine was added.

ANALYSIS OF VARIANCE OF AVERAGE DAILY GAIN

Source	d/f	SS	M.S.	F
Between treatments	5	843	16.9	1.63
Between litters	5	2952	59.	5.70**
Between sex	1	25	25.	2.41
Between basal rations	1	15	15.	1.45
Error	23	2384	10.35	
Total	35	6219		

** P .01

TABLE 11 -- THE EFFECT ON GROWTH RATE AND FEED EFFICIENCY OF SUPPLEMENTING PRACTICAL SWINE RATIONS WITH L-LYSINE AND DL-METHIONINE

EXPERIMENT 2, FALL, 1953

Lot	1	2	3	4	5	6	7
Ration	Basal A	A+L[1]	A+M[2]	A+L[1] +M[2]	Basal B	B+L[1]	B+M[2]
No. of Pigs	7	7	7	7	7	7	7
Avg. initial wt., lb.	31.4	30.3	30.4	30.9	31.0	30.6	30.1
Avg. final wt., lb.	113.7	120.2	126.4	119.0	119.3	120.9	115.0
Avg. daily gain, lb.	1.33	1.44	1.56	1.42	1.43	1.46	1.34
Avg. daily feed, lb.	4.58	4.63	4.80	4.36	4.55	4.32	4.15
Feed/cwt. gain, lb.	343	321	309	307	318	295	309

1/ 0.10 percent L-lysine was added as the hydrochloride
2/ 0.04 percent DL-methionine was added

ANALYSIS OF VARIANCE OF AVERAGE DAILY GAINS

Source	d/f	SS	M.S.	F
Between treatments	6	2173	362.2	13.2**
Between litters	6	4149	691.5	25.2**
Between sex	1	147	147	5.36*
Between basal rations	1	36	36	
Error	34	9331	27.4	
Total	48	15836		

* P .01
** P .05

TABLE 12 -- THE EFFECT ON GROWTH RATE AND FEED EFFICIENCY OF SUPPLEMENTING PRACTICAL SWINE RATIONS WITH L-LYSINE, DL-METHIONINE AND DL-TRYPTOPHAN

EXPERIMENT 3, SPRING, 1954

Lot No.	1	2	3	4	5	6	7	8	9	10
Ration	-AB[4]	+L[1]M[2]T[3]	Basal	+L[1]T[3]	+L[1]	+L[1]M[2]	-AB[4]	+T[3]	+M[2]	+M T[3]
No. of Pigs	6	6	6	6	6	6	6	6	6	6
Avg. initial wt., lb.	32.3	31.2	31.3	31.5	31.3	30.5	31.5	31.2	30.8	30.0
Avg. final wt., lb.	95.7	100.5	95.9	103.8	107.5	104.3	98.7	102.0	102.8	96.0
Avg. daily gain, lb.	1.11	1.22	1.13	1.27	1.34	1.30	1.18	1.25	1.27	1.16
Avg. feed consumed, lb.	3.51	3.64	3.61	3.76	3.69	3.66	3.63	3.64	3.64	3.61
Feed/cwt, gain, lb.	316	300	319	296	275	283	306	291	287	312

1 0.10 percent L-lysine was added as the hydrochloride
2 0.04 percent DL-methionine was added
3 0.04 percent DL-tryptophan was added
4 -AB Same as basal ration, but contained no antibiotic

ANALYSIS OF VARIANCE OF AVERAGE DAILY GAINS LOTS 2-7

Source	Df	SS	M.S.	F
Between treatments	5	571	114.2	1.14
Between litters	5	1693	338.6	3.37*
Between sex	1	11	11	
Error	24	2412	100.5	
Total	35	4687		

* P .05

TABLE 13 -- THE DIFFERENCE IN MEAN DAILY GAIN (FROM ALL PIGS OF THE SAME SEX WITHIN A LITTER) OF THE PIGS RECEIVING RATION A, RATION A PLUS L-LYSINE, AND RATION A PLUS LYSINE PLUS DL-METHIONINE.

SUMMARY OF THREE EXPERIMENTS

DIFFERENCE FROM MEAN DAILY GAIN OF ALL PIGS OF SAME SEX WITHIN A LITTER

Litter	Basal A	+Lysine	+Lysine and DL-Methionine
1	+0.17 lb./day	-.02 lb.	+.08 lb.
2	0	-.08	0
3	-.13	-.03	+.04
4	-.03	+.21	-.18
5	-.18	+.05	+.04
6	0	0	+.01
7	-.16	+.20	-.21
8	-.02	+.01	-.17
9	-.15	-.15	+.10
10	+.05	+.10	-.18
11	-.13	+.25	-.03
12	-.13	-.20	-.10
13	+.08	-.02	+.21
14	+.18	0	-.08
15	0	-.06	-.07
16	-.45	+.15	+.04
17	-.15	+.25	-.06
18	-.13	+.14	+.21
19	-.20	+.06	+.20
Total	-1.38	+.86	-.15
Average	-.07	+.05	-.01
Students t, Basal vs. L-Lysine		2.3	
Students t, Basal vs. L-Lysine + DL-Methionine		1.38	
Students t, for P = 0.05		2.101	

One of the most unexpected results was the failure of the combination of lysine, methionine and tryptophan or of any two of these amino acids in combination to produce a growth stimulation as great as that produced by lysine alone. The added amino acids may have been rapidly absorbed from the digestive tract, overloading the metabolic pool, and then were catabolized and excreted before the bound amino acids of the ration could be freed by digestive enzyme to enter the metabolic pool. Sheffner and Bergeim (1953) have shown that a dietary excess of amino acids will increase the rate of L-amino acid oxidation by rat kidney, and Schweigert (1947) and Suberlich *et al.* (1948) have shown that urinary excretion of free and bound amino acids is influenced by the ration.

Phillips and Berg (1954) have shown the depressing effects of feeding several D forms of amino acids to rats.

There is also the possibility that a critical ratio among several amino acids was altered. Almquist (1954) has recommended that poultry receive two parts of lysine to one part methionine and Albanese (1955) has indicated that human infants require seven parts of lysine to one part tryptophan for best performance. Similar ratios may exist for other amino acids.

The concept of amino acid imbalance has been reviewed by Harper (1956) who cites evidence showing the effects of excesses of several amino acids in the presence of borderline deficiencies of other essential amino acids.

In two experiment, pigs did not grow faster when supplements of lysine or methionine, or lysine + methionine were added to basal ration B. Similar results have been reported by Meade (1956). Dyer *et al.* (1949) obtained a growth stimulation when a 20 percent crude protein, corn-soybean oil meal ration was supplemented with methionine, but other investigators, using lower levels of protein, have not obtained growth responses from supplemental methionine (Ferrin, 1946; Catron, 1953). Corn protein contains 3 percent methionine and 1.6 percent cystine (Flynn *et al.,* 1954) and soybean meal proteins contain about 1.7 percent methionine and 1.7 percent cystine. Therefore, as the percent of protein in a corn-soybean oil meal ration decreases the concentration of sulfur amino acids expressed as a percent of the protein increases.

Becker *et al.* (1954) reported that a corn-soybean meal ration containing 14 percent of crude protein was satisfactory but a 16 percent corn-fish meal ration was required under their conditions. The corn-soybean ration contained 0.63 percent lysine, 0.23 percent methionine (no measurement of cystine) and 0.13 percent tryptophan. This corresponds to 4.5, 1.65 and 0.9 percent of the protein. The fish meal ration contained greater concentrations of lysine and methionine but was thought to be deficient in tryptophan.

Soybean meal has greater concentrations of glycine, phenylalanine + tyrosine, sulfur amino acids and arginine than shorts and tankage. Therefore, the addition of lysine to a corn-soybean meal ration should improve the amino acid balance. Shelton *et al.,* (1951a) obtained a lower lysine requirement (4.2 percent of protein) on a ration containing 10 percent gelatin, which is high in glycine, than was obtained by Brinegar *et al.* (1950a and b) on rations that did not supply large amounts of glycine.

The amounts of amino acids present in supplemented ration A, containing 16 percent crude protein (0.83 lysine, 0.56 methionine + cystine and 0.10 percent tryptophan), are less than the National Research Council's recommended allowance for pigs weighing between 25 and 70 pounds.

Corn and Wheat Shorts Rations

The performance of pigs fed the amino acid supplemented corn and

TABLE 14 -- THE PERFORMANCE OF PIGS FED A CORN/WHEAT SHORTS RATION SUPPLEMENTED WITH AMINO ACIDS COMPARED TO THAT OF PIGS FED A GOOD QUALITY RATION

Lot	1		2	
	a	b	a	b
No. Pigs	6	6	6	6
Average initial wt., lb.	30.8	96	31.0	95
Average final wt., lb.	96.1	206	86.1	203
Average daily gain, lb.	1.15	1.63	0.97	1.60
Average feed consumed	3.50	5.96	3.22	6.10
Feed, lbs./lb. gain	3.06	3.66	3.32	3.80

Period a, from weaning to weigh day when average wt. of lot 1 was nearest 100 lbs. Period b, from weigh day when each lot was nearest 100 lbs. until weigh day nearest 200 lbs.

wheat shorts ration is given in Table 14. The results are divided into two parts: (1) The performance up to 100 pounds and (2) the performance after 100 pounds. Pigs on the corn-shorts ration apparently were handicapped by amino acid shortage until they weighed 100 pounds. Thereafter, they gained nearly as rapidly and efficiently as those receiving the good quality ration. The amino acid requirement of the pigs after 100 pounds appeared to have been adequately met by 0.478 percent lysine, 0.416 percent methionine and cystine, and 0.14 percent tryptophan. These values as a percent of the protein are: Lysine, 4.0; methionine and cystine, 3.5; and tryptophan, 1.2. Pigs weighing less than 100 pounds did not receive sufficient amino acids from 0.529 percent lysine, 0.45 percent methionine and cystine, and 0.164 percent tryptophan. (As a percent of protein, these values are 3.8, 3.2, and 1.2 respectively). Lysine was undoubtedly the limiting amino acid.

The growth curves of the pigs in Experiment 5 are shown in Figure 4. Lot 1 made significantly faster gains than lots 2 or 3. The pigs made satisfactory growth. The average daily gains for the lots from weaning to 100 pounds were: Basal corn and shorts, 0.91; basal + 0.10 percent L-lysine, 0.03 percent DL-methionine, and 0.02 percent DL-tryptophan, 1.02; and basal + 0.20 percent L-lysine, 0.06 percent DL-methionine, and 0.04 percent DL-tryptophan, 1.16.

When all lots were fed the unsupplemented ration after reaching a mean weight of 100 pounds, the gains were not as rapid. However, they were more efficient than they had been in Experiment 4 when thrifty pigs that had been fed good quality rations were used as test animals.

If all experiments with the corn and wheat shorts rations are averaged, the pigs weighing 95 to 120 pounds, initially, gained 1.5 pounds per day and required 500 pounds feed per hundred pounds of gain. Pigs fed the same ration supplemented with lysine, methionine and tryptophan gained 1.6 pounds and required 380 pounds feed per hundred pounds of gain.

Pigs weighing 30 to 40 pounds, initially, gained 0.91 pounds with an efficiency of 471 pounds feed per hundred pounds of gain on the basal ration. Those fed the amino acid supplements gained 1.07 pounds per day and required 371 pounds feed per hundred pounds of gain.

Corn and Tankage Rations

The crossbred pigs that were fed the mixed corn and tankage rations were very thrifty and made excellent gains from weaning to 100 pounds. Results are summarized in Table 15. The poorest gains were made by the

TABLE 15 -- THE EFFECT OF ADDED DL-TRYPTOPHAN, DL-METHIONINE AND L-LYSINE·HCl ON THE AVERAGE DAILY GAINS (G) AND FEED EFFICIENCY (E) OF CROSSBRED PIGS FED A CORN TANKAGE RATION (WEANING TO 100 LBS.)

		Weight		Pig		
Lot	Ration	initial	final	Days	G.	E.
5	Basal	42.9	99.9	390	1.46	309
1	Basal + tryptophan	43.7	98.7	405	1.36	338
4	Basal + methionine	43.4	99.0	405	1.37	326
2	Basal + lysine	43.7	97.2	420	1.27	367
3	Basal + T + M	44.8	102.3	390	1.47	306
6	Basal + TML	43.5	103.4	390	1.54	294

lot receiving supplemental lysine. Apparently, this reflects a lysine imbalance and indicates that the pig does not conform to the lysine-methionine (L/M) and the lysine-tryptophan (L/T) ratios previously reported for chicks and human infants. The L/M and L/T of the basal ration were 1.95 and 6.03, somewhat below the 2.0 and 7.0 postulated as ideal. The lysine supplement raised these values to 2.1 and 6.5 but performance was not as good.

The performance of lot 6, receiving supplements of lysine, methionine and tryptophan was better than that of the basal lot. The L/M and L/T values were 1.9 and 4.8.

Since the separate addition of lysine, methionine or tryptophan failed to improve gain or feed efficiency, the pigs' requirements for these amino acids appear to have been met by the basal ration containing 0.65 percent lysine, 0.49 percent methionine + cystine and 0.11 percent tryptophan. However, the superior performance of Lot 6 pigs, receiving a combination of the amino acids, could indicate a requirement of 0.70 percent lysine, 0.53 percent methionine + cystine and 0.15 percent tryptophan.

As a percentage of the dietary protein, the requirements indicated are: Lysine, 4.3 and 4.7; methionine 3.3 and 3.5; and tryptophan 0.7 and 1.0. The higher figures agree remarkably well with those obtained on the corn-soybean meal and the corn, soybean meal, tankage and wheat shorts rations.

The results discussed above emphasize the need for caution when drawing conclusions about amino acid requirements determined by the comparison method.

Pigs in Experiment 7 wasted a great deal of feed so the feed efficiencies are not very reliable. The lot receiving the supplement containing tryptophan gained slightly faster than the others. Results are shown in Table 16. The increase in performance was not enough to pay for the amino acid. The results were slightly better than those obtained in Experiment 6, where the tryptophan was mixed in a complete ration.

TABLE 16 -- THE EFFECT OF ADDING TRYPTOPHAN TO TANKAGE SELF FED TO GROWING FATTENING PIGS

	1	2
No. of pigs	10	10
Starting weight, lb.	36.0	37.1
Final weight, lb.	180.7	185.8
Average daily gain, lb.	1.41	1.45
Feed Consumed		
Corn, lb.	4450	4600
Supplement, lb	975	884
Feed per cwt gain		
Corn	308	309
Supplement	67	59
Total	375	368

Synthetic Rations

Data obtained in the experiments with synthetic rations are presented in Tables 17 and 18. None of the differences between lots in growth rate were significant. However, some definite trends were noted. The best growth was obtained on the dried whole egg and the casein-purified rations. A mixture of proteins was no better than casein or dried whole egg alone. One of the unexpected results was the finding that pigs grow as well on a mixture of corn and egg at the 12 percent protein level as they did on a mixture of corn starch and whole egg protein. The addition of lysine and tryptophan to the corn and egg ration did not improve the performance of weanling pigs. This indicates that the lysine requirement for growth at the 12 percent level is less than has been indicated in previous investigations.

Table 19 gives the results of Experiment 10. They indicate that the addition of 3 percent of alfalfa meal and 3 percent of fish meal to a ration for weanling pigs did not improve the rate of gain. The mixture of corn and casein was no better than the basal ration, indicating that while casein alone is an excellent source of protein when fed to supply 18 percent protein, it is not superior to a mixture of tankage, soybean meal,

TABLE 17 -- THE VALUE OF PURIFIED RATIONS FOR WEANLING PIGS

Lot	1	2	3	4	5	6	7	8
Protein source	S 1/	C 2/	L 3/	S + C	S + L	C + L	C + L + A 4/	S + A 4/
No. of pigs	3	3	3	3	3	3	3	3
Average initial wt., lb.	32.7	32.3	32.3	31.3	32.3	33.0	32.0	31.7
Average final wt., lb.	97.0	107.7	98.7	97.7	98.3	102.0	102.3	97.7
Average daily gain, lb.	1.15	1.35	1.18	1.25	1.18	1.23	1.26	1.18
Average daily feed, lb.	3.2	3.2	3.1	3.4	3.2	3.2	3.2	3.2
Feed/cwt. gain, lb.	277	236	265	265	269	257	252	278
Gain/lb. protein eaten, lb.	2.03	2.35	2.10	2.10	2.06	2.16	2.20	2.06

1 soybean meal
2 casein
3 liver
4 antibiotic

TABLE 18 -- THE VALUE OF WHOLE EGG IN THE RATION OF WEANLING PIGS WINTER 1953

Lot	1	2	3
Ration	Corn & Egg	Corn & Egg + L-lysine + DL-tryptophan	Corn starch + Egg
No. of pigs	3	3	3
Average initial wt., lb.	32	32	33
Average final wt., lb.	75	74	81
Average daily gain, lb.	1.23	1.19	1.24
Average daily feed, lb.	3.92	3.85	3.74
Feed/cwt. gain, lb.	320	323	302
Gain/lb. protein eaten, lb.	2.60	2.54	2.76

TABLE 19 -- THE COMPARATIVE VALUE OF CORN AND WHEAT SHORTS SUPPLEMENTED WITH AMINO ACIDS, CORN, CASEIN, AND ALFALFA-FISH MEAL SUPPLEMENTED RATIONS FOR WEANLING PIGS

Lot	3	11	12	13
Treatment	Basal A	Basal A + Fish meal & Alfalfa	Corn-Casein	Corn, wheat Shorts & Amino acids
Number of pigs	6	6	6	6
Number of pig days	342	342	342	342
Average initial wt., lb.	31.3	30.8	31.0	31.0
Average final wt., lb.	95.9	96.1	96.0	86.1
Average daily gain, lb.	1.13	1.15	1.15	0.97
Average feed consumed, lb.	3.61	3.50	3.25	3.22
Feed/cwt. gain, lb.	3.19	3.06	2.86	3.32
Gain/lb. protein eaten, lb.	2.0	2.1	2.2	2.1

shorts and corn when fed at the 16 percent level of protein.

The pigs fed the corn and shorts ration supplemented with purified amino acids did not gain as rapidly as those fed the basal ration but the differences were not significant. Published requirements for lysine appeared excessive for the slow growing strain of pigs used in this experiment. The supplemented ration of ground corn and shorts, which contained less lysine than published requirements called for, produced satisfactory growth rate.

Feed Efficiency

Practical Rations:

The addition of lysine to ration A and B increased feed efficiency over the basal lots ($N = 5$, $P < 0.05$).

The addition of methionine to basal A increased feed efficiency ($N = 3$, $P < 0.02$). The addition of lysine and methionine increased feed efficiency of ration A ($P < 0.05$) but did not increase feed efficiency of ration B.

In experiment 3 pigs receiving supplements of tryptophan, tryptophan + lysine, and tryptophan + lysine + methionine required less feed per hundred pounds of gain than the pigs in the basal lot.

The average increase in feed efficiency from the lysine supplemented rations was an additional 50 pounds of live hog per ton of feed. This indicates that lysine supplementation of rations similar to those used in these experiments would be economical if 2 pounds of lysine cost less than the value of 50 pounds of live hog.

Purified Rations:

Results from single tests on feed efficiency of pigs fed the purified rations cannot be subjected to statistical analysis because the lots were group-fed; however, as would be expected, the protein efficiency was greatest in the rations containing amino acids in good balance. The best feed efficiency was obtained with the casein-purified ration, fed at 18 percent crude protein, and the poorest feed efficiency was obtained in the corn and shorts ration. The greatest protein efficiency was obtained in the lots fed cornstarch and whole egg protein at the 12 percent level, followed in order by corn and whole egg, corn and egg supplemented with lysine, and the casein-purified ration. Lowest protein efficiency was obtained with corn and shorts, followed by basal ration A, indicating that proteins of soybean meal, tankage, corn, and shorts were inferior to whole egg. The differences however, were not great enough to be of much practical significance.

Although an increase in feed efficiency was generally obtained in previous experiments from rations which contained dried alfalfa meal and fish meal in rations for small or stunted pigs (unpublished data), no response was obtained from additional fish meal in this experiment with larger, thriftier pigs.

Amino Acid Requirements

Some of the rations used in these experiments were analyzed for amino acids. The apparent requirements on several test rations were calculated, using the analyses and the response of the pigs. These are summarized in Table 20. Expressed as a percentage of protein of the ration, the needs of the Chester White pigs used apparently were met by 1 percent of tryptophan and 3.5 percent of methionine + cystine.

The requirement for lysine seems to have been higher on the high protein diet. The 12 percent crude protein, corn, and egg ration which contained 0.51 percent lysine (4.26 percent of the protein) was not improved by supplementation with lysine and gave as good results as the 12

TABLE 20 -- THE APPARENT REQUIREMENTS OF CHESTER WHITE PIGS FOR LYSINE, TRYPTOPHAN AND METHIONINE + CYSTINE FROM WEANING TO 75 LBS.

		Apparent Requirements					
		Lysine		Tryptophan		Methionine + Cystine	
Ration	% CP	% Ration	% Prot.	% Ration	% Prot.	% Ration	% Prot.
Casein-purified	18	*	*	*	*	.63	3.5
CSTSh	18	1.0	5.6	*	*	.59	3.3
CSTSh	16	.83	5.2	.18	1.1	.54	3.4
CSTSh	14	.63	4.5	.14	1.0	.45	3.2
Corn soy	16	.77	4.8	*	*	.58	3.6
Corn shorts	14	.60	4.25	.14	1.0	.42	3.0
Amino acids Corn-whole egg	12	.48	4.0	.12	1.0	*	*

* Ration contained an excess of the amino acid.

percent whole egg ration containing 0.88 percent lysine (7.25 percent of protein). Neither were the corn and soybean oil meal rations (containing 14, 16 and 18 percent of protein, of which 4.3, 4.7, and 4.8 percent was lysine) improved by the addition of lysine. But mixed rations of corn, shorts, tankage, and soybean oil meal (containing 14, 16 and 18 percent crude protein, of which 4.2, 4.5 and 4.8 percent was lysine) were improved in three tests by the addition of 0.1 to 0.15 percent of lysine, added as L-lysine mono-hydrochloride. However, if the amino acid requirements are expressed as a percentage of the protein, the levels which were satisfactory in these studies approach those recommended by the National Research Council (lysine, 5.2 vs. 6.0; methionine, 3.5 vs. 3.6; and tryptophan, 1.0 vs. 1.2).

It seems desirable to make recommendations in terms of percentage of protein rather than percentage of ration. This system has been recommended by Almquist (1953) for poultry and by Brinegar (1950) for swine.

The higher requirements obtained in early experiments (Brinegar, 1950) may have resulted from the use of unbalanced proteins and large levels of free amino acids for supplements and to shortages of one or more nutrients in the ration. The importance of having all amino acids present in the pool is emphasized by the reports of Cannon *et al.* (1947) and Geiger *et al.* (1950). Cunha *et al.* (1949) demonstrated that the requirement for methionine was lower when vitamin B_{12} was present in the ration. The conversion of tryptophan to niacin is well known (Leucke, 1947, 1948; Powick, 1948).

Amino acid imbalances were discussed by Grau and Kamei (1950). Salmon (1954) suggested that a downward revision of amino acid requirements would be possible when rations well balanced in amino acids are formulated. Before exact requirement figures can be given, it will probably be necessary to express the form in which the amino acid was fed. Many of the published requirements were based on free amino acid supplementation of rations which were nearly free of the amino acid under test. For example, Brinegar *et al.* (1950a and b), and Mertz *et al.* (1949) used rations that were very low in lysine and supplemented them with free lysine. It is doubtful that the utilization of amino acid mixture would be the same if a few of the amino acids were being supplied in pure form and others were joined in the protein molecules.

Compared with pigs used by Brinegar and Mertz to measure amino acid requirements, pigs on the current experiments grew as fast or faster during the same period of time on lower levels of lysine.

The fact that some pigs on the unsupplemented rations grew at faster rates than litter mates receiving the supplemented rations indicates that the lysine requirement is variable. Before controlled nutritional experiments can produce additional refinements in the requirement figures, the variability between litters must be reduced.

The response to amino acid supplements may also depend on other factors. Recently the methionine requirement of broilers has been related to the energy level of the ration (Baldini, 1955). Gordon and Maddy (1956) have suggested a formula for estimating requirements that uses both protein and energy levels of the ration.

Differences due to breed, climate, growth rate, and management factors may be identified.

Responses obtained at other stations are summarized in Table 21.

At present, methionine is the only amino acid that has been tested which is economical enough to add to swine rations. At its current price of $2.00 to $3.00 per pound it would seem to have some value if added to rations formulated from grains other than corn. Corn contains more sulfur amino acids than any of our other farm grains.

If lysine and tryptophan become available at similar prices, it should be possible to increase the growth rate and feed efficiency obtained with many formulas for young swine by supplementing them with amino acids.

Some of the pigs in the amino acid studies were fed to 200 pounds on a uniform ration. The pigs that received the basal ration until they weighed 100 pounds gained as rapidly from 100 to 200 pounds as the pigs that received the supplemental rations. Other experiments with protein supplements indicate that many feeds contain fairly adequate levels of the amino acids for pigs weighing 100 to 200 pounds.

Work at Oklahoma A & M (Reber and MacVicar, 1953) indicates that young growing pastures contain an excellent distribution of amino acids. We would therefore expect the response to amino acid supplements to be less on pasture than it was in these drylot experiments.

A number of questions about the use of supplemental amino acids in swine rations still need to be answered. Future research should be directed toward determining: (1) whether or not the pig can utilize the D form of the amino acids as efficiently as he can the L form; (2) whether the analogs of amino acids can be used as satisfactorily as the amino acids; and (3) the nature of the imbalances and interrelationships of the amino acids and their availability to tissues of the pig.

TABLE 21 -- THE EFFECT OF SUPPLEMENTING PRACTICAL RATIONS WITH AMINO ACIDS ON DAILY GAIN (G) AND FEED EFFICIENCY (E) OF WEANLING PIGS.

Experiment station & year	Weight of pigs (lbs.)	Protein source (s)	Level of crude protein in ration	Response to supplemental amino acids					
				Lysine		Methionine		Tryptophan	
				G	E	G	E	G	E
Purdue--1954	30-125	Corn-tankage	14.5	0	0	-	0	+	+
Purdue--1954	30-125	Corn-meat scraps	14.5					+	+
Arkansas--1954,1955	Varied	Corn-cottonseed	16	+	+			+	+
Michigan--1953	30-65	Corn-meat scraps	17					+	+
Oklahoma--1953	30-120	Corn-soy	12	+	+				
Oklahoma--1953	30-120	Milo-soy	14	+	+				
Iowa--1953	23-100	Corn-soy	12	+	+	0	0		
Iowa--1953	23-100	Corn-soy	14	0	0	0	0		
Georgia--1952	36-100	Corn-CSOM	20	+	+	+	+		
Nebraska--1953	50	Corn	8	+	+			+	+
USDA--1951		Corn-soy		0	-	+	0		
Minnesota--1946	50-200	Corn-soy	17			0	0		
Illinois--1954	36-100	Corn-meat scraps	18					+	+
Illinois--1949	30-100	Corn-soy	20			+	+		

SUMMARY

A survey of literature was made on the amino acid requirements of swine and the amino acid compositions of typical swine feeds. A number of practical swine rations were estimated to be deficient in lysine, methionine, or tryptophan.

Three feeding experiments were conducted with pigs from weaning to about 100 pounds to determine the effect of supplementing practical rations with lysine, methionine and tryptophan. The practical rations consisted of corn, soybean meal, tankage and wheat shorts (basal A) containing 14, 16 and 18 percent of protein. The addition of 0.1 percent of L-lysine increased growth rate and feed efficiency but did not greatly increase feed consumption. Supplements of methionine and tryptophan increased growth rate and feed efficiency, but combinations of 2 or 3 amino acids did not give as much response as lysine alone.

Two experiments were conducted to determine the effect of supplementing a corn and soybean meal ration containing 14, 16 and 18 percent crude protein with lysine and methionine. Neither supplement, alone or in combination with the other, increased growth rate, but both improved feed efficiency slightly.

The best protein efficiency was obtained with a purified ration of cornstarch and whole egg protein fed at the 12 percent level, but the daily gain on this ration was no better than on basal ration A.

The addition of 3 percent of fish meal and 3 percent of alfalfa meal did not improve performance of pigs fed basal ration A.

When corn and shorts rations containing 14 and 12 percent of crude protein were supplemented with lysine, methionine, and tryptophan, the growth rates and feed efficiencies of pigs were only slightly lower than those from rations containing conventional protein supplements.

Corn and tankage rations containing 15 percent crude protein were not greatly improved by additional tryptophan and growth was depressed if lysine was added to them. Tryptophan supplementation improved a self fed shelled corn and tankage ration slightly. Corn and wheat shorts rations were markedly improved by the addition of purified amino acids.

Requirements of the Chester White pig for sulfur amino acids and tryptophan, expressed as a percentage of protein, apparently were met by 3.5 percent of methionine + cystine, and 1 percent of tryptophan. The lysine requirement appeared to vary with protein intake. Estimates ranging from 4.25 percent on a 12 percent crude protein ration to 5.5 percent on 18 percent crude protein rations were obtained.

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APPENDIX

TABLE 1 -- THE ESTIMATED AMINO ACID REQUIREMENTS OF THE WEANLING PIG - A LITERATURE SURVEY AND CALCULATIONS

Amino Acid	Requirements Expressed As: % of Ration	Requirements Expressed As: % of Protein	Determined By:	Reference	Remarks
Arginine	0.2% adequate	---	feeding amino acids and diammonium citrate	Mertz, et al. 1952	
	---	4.6	carcass analysis	Curtin et al. 1952	
Histidine	---	1.8	carcass analysis	Curtin et al. 1952	
Isoleucine	0.23% in ration + 1.2% DL 0.7% L	2.9	feeding 23.68% blood flour + 0.4% D meth. (20.8% CP)	Brinegar et al. 1950 C	
	---	2.6	carcass analysis	Curtin et al. 1952	
Leucine	1.25	5.0	feeding 25% semisynthetic milk	Eggert et al. 1954	
	---	4.6	carcass analysis	Curtin et al. 1952	
Lysine	0.63	4.5	calculation: analysis adequate 14% corn soy basal ration	Becker et al 1954	analysis of ration lower than expected
	0.55	4.6	calculation: 12% CP corn soybean meal + 0.1% DL or 14% CP corn milo + 0.10% L lysine	Pond et al. 1953	
	0.60	5.0	calculation: 12% CP corn soybean meal improved by 0.1% lysine	Catron. 1953	
	0.8-1.0%	3.36-4.2	feeding 16% zein, 10% gelatin, 0.3% DL-Try, 0.5% DL-M, 0.2% DL Hist HC1 (23.8% CP) supplemented with lysine	Shelton, et al. 1951 A	
	0.58 L lysine	5.8	feeding 28.37 linseed, 0.3 DL-M, 0.10 Hist HC1 (9.85% CP)	Brinegar et al. 1950	
	1.17 L lysine	5.5	feeding 45.45% sesame, 0.4 DL-M, 0.13% Hist HC1 (21.1% CP)	Brinegar et al. 1950	

	1.20 L lysine	5.5	feeding 15.13 meat & bone, 4.2 zein, 70.86 wheat, 0.50 DL-M, 0.24 Hist HC1, O.1 DL Tryp (22% CP)	Brinegar _et al._ 1950	
	2% DL lysine HC1 0.8% L lysine	3.1	feeding 23.5 zein, 0.4% DL tryp, 0.13 glycine, 0.17 L hist, (26% CP)	Mertz _et al._ 1949	
Methionine	---	1.20	carcass analysis	Curtin _et al._ 1952	
	0.23	1.65	calculation: analysis of 14% corn soy & 16% corn-fish	Becker _et al._ 1955 A	
	0.07 + 0.20 DL-M adequate	2.7	feeding 21.36 soybean oil meal - purified (10% CP)	Bell _et al._ 1950	analysis SBOM appears low
	0.3% Meth + 0.3% cys	2.8	feeding oxidized casein, gelatin, 0.3% DL Tryp (21% CP)	Shelton _et al._ 1951 A	2 pigs on each level
	.51 Meth .34 C	2.5 1.7	calculation: growth response to 0.2% DL Meth on 20% CP ration 63.5 corn, 34 soybean	Dyer. _et al._ 1949	
	0.45 M 0.26 C	3.2	feeding alpha protein 21.3, yeast 5 (22% CP)	Curtin _et al._ 1952	
	.29 M + .20 C	2.4% M 4.1% Total	calculation: 12% CP corn and soy, no help from methionine	Catron _et al._ 1953	
	---	---	calculation: 17% CP corn soy- no help from methionine	Ferrin, E. F. 1946	
	0.41% M + .38% C	3.6% Total	feeding solvent soybean meal- purified (22% CP)	Curtin _et al._ 1952	Meth. req. from log plot
Phenyl-alanine	not more than 0.23 phenyl-alanine + 0.14 tyrosine	1.77 P 2.85 Total	feeding 66% corn, 5.48% E.A.A., 2.5% (NH2)2 citrate, 13% CP	Beeson _et al._ 1953	
	---	4.1 Total	carcass analysis	Curtin. 1952	
Threonine	.9	3.6	feeding alpha protein 11.19, amino acid mix, ammonium citrate	Sewell _et al._ 1953	
	.4	3.0	feeding corn + amino acids	Beeson _et al._ 1953	
	---	2.4	carcass analysis	Curtin _et al._ 1952	

TABLE 1 (continued)

Amino Acid	Requirements Expressed As: % of Ration	% of Protein	Determined By:	Reference	Remarks
Tryptophan	0.4% DL adequate	.62	feeding supplemented 26.1% hydrolyzed fish protein	Beeson *et al.* 1948	estimated 15.7% CP
	0.2% DL	.82	feeding 16% zein, 10 gelatin, 0.5 DL Meth, 1.3 DL lysine HC1, 0.2 L Hist HC1 (24.5% CP)	Shelton *et al.* 1951	
	Less than 0.25% DL	1.0	calculation: 40% corn, 20.7% casein. OK if adequate niacin	Powick *et al.* 1948	
	.42% DL	1.9	40 corn, 13.8 casein, 16.9 gelatin OK if 0.25 tryp added	Powick *et al.* 1948	
	.12	80	calculation: 87 corn, 5.5 casein, 5.5 soy (15.1% CP)	Luecke *et al.* 1948	
	.16	.94	calculation: 17% corn-meat scrap improved by .06% DL tryp or replacing 1/2 meat scraps with soybean meal	Bloss *et al.* 1953	
	.13	.9	calculation and analysis of adequate corn soy (14% CP) ration	Becker *et al* 1954	
	---	.5	carcass analysis	Curtin *et al.* 1952 A	
Valine	0.4	3.6 dig.	feeding corn + amino acids (12.8% CP)	Jackson *et al.* 1953	
	---	3.9	carcass analysis	Curtin *et al.* 1952 A	

TABLE 2 -- THE AMINO ACID COMPOSITION OF FEEDSTUFFS

Feedstuffs	NX 6.25	True(T) or apparent(C) Dig. of Protein	Arginine		Histidine		Isoleucine		Leucine		Lysine		Methionine		Cystine		Phenyl Alanine		Tyrosine		Threonine		Tryptophane		Valine		Glycine	
			Mean	±	Mean	±	Mean	±	Mean	±	Mean	±	Mean	±	Mean	±	Mean	±	Mean	±	Mean	±	Mean	±	Mean	±	Mean	±
Alfalfa Meal	17.0	79T	0.81	±.05	0.31	±.01	0.81	±.06	1.15	±0.03	0.84	±0.06	0.33	±.05	0.30	±.04	0.74	±.02	0.78	±.23	0.58	±.02	0.26	±.04	0.82	±.12	----	----
Barley	11.0	90T	0.51	±.04	0.21	±.03	0.44	±.02	0.65	±0.08	0.28	±0.08	0.18	±.07	0.20	±.01	0.50	±.07	0.15	±.05	0.34	±.10	0.13	±.02	0.49	±.06	0.30	----
Blood Meal	80.0	78C	3.22	±.15	3.82	±.16	0.99	±.07	9.85	±0.80	6.89	±0.11	1.07	±.12	1.48	±.03	5.26	±.44	2.98	±.03	4.36	±.60	1.09	±.09	6.17	±.13	----	----
Buttermilk, Dried	32.5	93C	1.08	±.15	0.83	±.02	2.47	±.21	3.26	±0.29	2.27	±0.14	0.73	±.12	0.35	±.07	1.48	±.23	1.18	±.45	1.41	±.01	0.42	±.01	2.57	±.11	0.70	----
Casein	85.0	99	3.43	±.10	2.55	±.09	5.49	±.13	8.54	±0.31	6.72	±0.02	2.84	±.14	0.27	±.01	4.66	±.08	5.63	±.33	3.52	±.15	1.06	±.06	5.91	±.19	1.80	----
Cocoanut Oil Meal	20.0	73C	2.20	----	0.34	----	0.80	----	1.00	----	0.50	----	0.31	----	----	----	0.86	----	----	----	0.70	----	0.18	----	1.10	----	----	----
Corn	9.0	94T	0.40	±.04	0.23	±.04	0.39	±.04	1.46	±0.43	0.22	±0.05	0.25	±.02	0.14	±.02	0.43	±.03	0.49	±.06	0.32	±.03	0.07	±.01	0.46	±.02	0.37	±0.02
Corn Germ Meal	20.0	85T	1.50	----	0.58	----	0.76	----	2.80	----	1.20	----	0.31	----	0.32	----	1.10	----	1.20	----	0.92	----	0.26	----	1.20	----	----	----
Corn Gluten Feed	25.0	75C	0.61	----	0.63	----	1.10	----	2.80	----	0.68	----	0.25	----	----	----	0.90	----	0.38	----	0.88	----	0.14	----	1.30	----	----	----
Corn Gluten Meal	41.0	86C	1.30	±.03	0.80	±.15	2.06	±.04	8.02	±1.18	0.65	±0.19	0.96	±.05	0.63	±.15	2.51	±.26	2.58	±.25	1.41	±.23	0.26	±.07	2.30	±.30	1.73	±0.04
Cottonseed Meal	41.0	90T	3.53	±.19	0.97	±.06	1.53	±.03	2.24	±0.24	1.45	±0.29	0.72	±.09	0.87	±.06	2.22	±.34	1.19	±.16	1.25	±.12	0.52	±.07	1.87	±.21	2.26	±0.06
Distillers Dark Grains	28.0	73C	0.89	----	0.43	----	1.70	----	2.00	----	0.71	----	0.45	----	----	----	1.70	----	0.53	----	0.98	----	0.17	----	1.60	----	----	----
Distillers Solubles	28.0	60C	0.96	±.37	0.70	±.04	1.61	±.09	1.68	±0.18	0.98	±0.42	0.48	±.14	0.24	±.05	1.68	±.07	0.59	±.02	0.96	±.04	0.15	----	1.51	±.13	----	----
Eggs, Contents	13.3	100T	0.85	±.01	0.30	±.02	0.99	±.09	1.22	±0.01	0.94	±0.10	0.54	±.09	0.32	±.01	0.77	±.10	0.62	±.02	0.63	±.02	0.20	±.01	0.96	±.02	0.30	±0.02
Flax Seed	22.0	91C	1.50	----	0.42	----	0.66	----	1.30	----	0.44	----	0.51	----	0.42	----	1.30	----	0.99	----	0.88	----	0.37	----	1.60	----	----	----
Fish Meal	60.0	92C	3.65	±.19	1.44	±.10	3.02	±.08	5.10	±0.52	4.97	±0.62	1.80	±.05	1.08	±.49	2.64	±.15	1.79	±.17	2.61	±.25	0.67	±.15	3.56	±.32	3.75	±0.64
Fish Meal, Sardine	65.0	94C	4.28	----	1.61	±.04	3.53	±.21	4.64	±0.01	5.16	±1.04	2.13	±.09	0.81	±.15	2.66	±.16	2.85	±.05	2.72	±.20	0.84	±.05	3.92	±.13	4.00	±0.56
Fish Solubles	33.5	96C	1.35	----	1.19	±.34	0.47	±.13	0.68	±0.08	1.40	±0.10	0.47	±.12	0.41	----	0.56	±.08	0.24	±.01	0.62	±.18	0.25	±.10	0.84	±.04	2.20	----
Garden Peas	25.6	89C	2.00	±.43	0.31	----	1.00	----	1.60	----	1.35	±0.07	0.20	----	0.32	±.02	1.20	----	----	----	1.00	----	0.18	±.01	1.00	----	----	----
Gelatin	95.0		8.46	±.96	0.82	±.16	1.82	±.14	3.39	±0.44	4.86	±0.18	0.75	±.01	0.10	±.01	2.09	±.10	0.42	±.33	1.94	±.27	----	----	2.73	±.10	23.55	±1.63
Linseed Meal	34.0	90C	2.70	±.08	0.66	±.07	1.69	±.15	2.21	±0.17	0.98	±0.10	0.74	±.07	0.63	±.04	1.82	±.08	1.75	±.06	1.36	±.32	0.53	±.02	2.11	±.21	----	----
Liver Meal	65.0	97T	3.85	±.35	1.60	----	3.10	----	5.40	----	4.10	----	1.60	±.14	0.90	±.01	3.10	----	2.30	----	2.50	----	0.79	±.10	3.70	----	----	----
Meat Scrap	55.0	82C	3.80	±.12	1.16	±.17	2.29	±.83	4.02	±0.66	3.54	±0.68	1.02	±.17	0.64	±.10	2.20	±.29	1.85	±.21	2.00	±.18	0.38	±.04	2.83	±.30	2.35	±0.22
Meat and Bone Scraps	50.0	89C	3.00	----	0.90	----	1.40	----	3.10	----	2.70	----	0.70	----	0.60	----	1.70	----	1.00	----	1.80	----	0.35	----	2.30	----	0.20	----
Milk Whole	3.5	97C	0.13	±.07	0.09	----	0.25	±.03	0.37	±0.03	0.26	±0.03	0.11	±.01	0.04	----	0.19	±.01	0.19	----	0.16	±.01	0.05	±.01	0.27	±.02	0.08	----
Milk Skim, Dried	34.0	98C	1.19	±.05	0.94	±.16	2.08	±.08	3.42	±0.41	2.55	±0.05	0.85	±.09	0.42	±.01	1.64	±.11	1.31	±.52	1.43	±.15	0.44	±.02	2.53	±.23	0.45	±0.36
Milo	10.5	87T	0.38	±.06	0.23	±.03	0.51	----	1.31	±0.09	0.27	±0.02	0.14	±.03	0.20	----	0.46	±.01	0.18	----	0.29	±.02	0.09	±.01	0.54	±.04	----	----
Molasses, Blackstrap	3.6								----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1.50	----	----	----
Oats	11.0	78C	0.64	±.04	0.25	±.01	0.53	±.03	0.81	±0.16	0.36	±0.03	0.19	±.06	0.19	±.02	0.54	±.04	0.40	±.13	0.37	±.07	0.15	±.04	0.66	±.13	0.26	----
Peanut Meal	44.0	94C	4.38	±.38	0.88	±.07	1.60	±.19	2.59	±0.37	1.32	±0.13	0.49	±.06	0.70	----	2.25	±.08	1.87	±.07	0.88	±.21	0.46	±.06	2.26	±.64	2.48	±0.02
Potato Meal, Sweet	7.4	57T	0.21	----	0.10	----	0.27	----	0.33	----	0.28	----	0.96	----	----	----	0.20	----	----	----	0.28	----	0.13	----	0.41	----	----	----
Potato Meal, White	8.2	89T	0.43	----	0.18	±.08	0.30	----	0.48	----	0.47	----	0.07	----	----	----	0.29	----	----	----	0.38	±.25	0.15	----	0.41	±.02	----	----
Rice	11.22	86C	0.60	----	0.25	----	0.44	----	0.51	----	0.24	±0.06	0.12	±.02	0.10	----	0.31	----	----	----	0.22	----	0.10	----	0.40	----	----	----
Rice Bran	12.8	83T	0.64	±.16	0.17	±.04	0.43	±.06	0.60	±0.08	0.45	±0.05	----	----	0.11	----	0.41	±.05	----	----	0.29	±.01	0.10	----	0.62	±.07	----	----
Rice Polish	12.4	79C	0.52	±.10	0.15	±.07	0.34	±.02	0.48	±0.03	0.42	±0.03	----	----	0.13	----	0.34	----	----	----	0.28	±.06	0.12	----	0.50	----	----	----
Rice, Polished	7.5	97T	0.54	----	----	----	----	----	0.67	±0.02	0.24	----	0.25	±.01	0.11	----	0.50	----	0.42	----	0.31	----	0.10	----	0.47	----	0.77	----
Rolled Oats	15.0	93T	0.93	±.03	0.32	±.01	0.77	±.07	1.20	±0.06	0.54	±0.06	0.30	±.06	0.26	±.01	0.92	±.12	0.69	----	0.53	----	0.19	±.01	0.96	±.01	----	----
Rye	11.5	81C	0.49	±.01	0.21	±.02	0.47	±.01	0.69	±0.02	0.44	±0.04	0.16	±.02	----	----	0.57	±.07	0.18	±.08	0.35	±.03	0.14	±.02	0.56	±.01	----	----
Sesame Meal	41.0	92T	3.70	±.07	0.62	----	1.98	----	3.09	±0.01	1.18	±0.03	1.32	±.06	0.54	----	3.40	----	1.78	±.03	1.49	±.01	0.66	±.09	2.10	±.01	3.80	----
Soybean Meal	44.0	91C	2.98	±.18	1.05	±.05	2.24	±.09	3.17	±0.30	2.75	±0.22	0.74	±.15	0.73	±.09	2.24	±.26	1.48	±.39	1.75	±.17	0.59	±.13	2.44	±.59	7.30	±0.28
Sunflower Meal	46.0	94T	3.74	±.05	0.79	----	2.40	±.01	2.85	----	1.89	±0.10	1.59	±.03	0.69	±.05	2.45	±.05	1.20	----	1.84	----	0.60	±.01	2.40	±.01	1.84	----
Tankage	60.0	83T	3.57	±.02	1.60	±.01	1.72	±.07	4.79	±0.26	4.05	±0.29	0.62	±.02	----	----	2.92	±.17	1.69	±.13	1.85	±.07	0.43	±.02	3.26	±.07	----	----
Wheat	12.0	91T	0.50	±.06	0.24	±.04	0.48	±.09	0.81	±0.16	0.32	±0.04	0.22	±.06	0.21	±.02	0.66	±.04	0.49	±.03	0.36	±.04	0.15	±.03	0.58	±.09	0.86	±0.04
Wheat Bran	15.6	76C	0.93	±.11	0.33	±.07	0.59	±.05	0.86	±0.06	0.54	±0.03	0.20	±.06	0.23	±.04	0.51	±.01	0.18	±.01	0.36	±.03	0.22	±.02	0.76	±.07	0.91	----
Wheat Flour	10.7	100T	0.36	----	0.21	----	0.42	----	0.78	----	0.22	----	0.11	----	0.20	----	0.57	----	0.35	----	0.27	----	0.09	----	0.42	----	0.77	----
Wheat Mids	16.0	90C	0.84	±.04	0.42	±.02	0.76	----	0.90	----	0.42	±0.01	0.22	±.02	0.20	±.02	0.69	----	0.20	±.01	0.44	±.03	0.17	±.03	0.83	----	0.44	±0.01
Whey, Dried	12.0	91C	0.33	±.07	0.46	±.39	0.71	±.03	1.02	±0.05	0.82	±0.16	0.34	±.05	0.33	±.06	0.39	±.05	0.22	±.15	0.60	±.04	0.21	±.06	0.68	±.03	----	----
Yeast	4.5	93T	1.95	±.05	1.13	±.25	2.57	±.17	3.29	±0.14	3.29	±0.13	0.79	±.14	0.50	±.06	1.84	±.12	1.54	±.09	2.44	±.09	0.47	±.20	2.54	±.20	3.40	----