1976

The Nutritive Value of High Protein Oats, Double Mutant, Waxy, Opaque-2 and Normal Corns in Pig Starter Diets

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THE NUTRITIVE VALUE OF HIGH PROTEIN OATS, DOUBLE MUTANT, WAXY, OPAQUE-2 AND NORMAL CORNS IN PIG STARTER DIETS

BY

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A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Animal Science, South Dakota
State University

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

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ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to his advisor, Dr. Richard C. Wahlstrom, for his assistance and understanding during the course of these studies and during the preparation of this thesis.

Special appreciation is extended to Dr. George W. Libal for his encouragement, cooperation and advice given to me throughout my graduate studies; to Dr. William L. Tucker, Experiment Station Statistician, for his assistance in analysis of the data; and to my co-workers at the Swine Unit who cared for the experimental animals and aided in the collection of the data.

I would also like to extend a special thanks to my fellow graduate students for their helpful suggestions and criticisms.

I am grateful to Mrs. Anna Baumiller for typing this manuscript.

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INTRODUCTION

Most cereal grain proteins are of poor biological value because they lack sufficient quantities of certain amino acids necessary for proper body function. Protein supplements, one of the most expensive ingredients in swine diets, are actually used for their ability to supplement the amino acids needed in swine diets. Because the young pig has a high requirement for essential amino acids, an improvement in protein quality of feed grains could reduce the amount of supplemental protein needed in starter diets and thus reduce feed costs.

With the advent of opaque-2 corn and its improved protein quality, much research has been conducted in attempts to further improve the quality and quantity of cereal grain protein. Although it is doubtful that any one ingredient can furnish all the essential constituents needed in a balanced diet, great strides have been made in developing grains that can supply all of the energy and a large portion of the essential amino acids in the diets of weanling pigs.

The value of the mutant corns has been demonstrated in their ability to support superior performance of animals consuming them and in the need for less supplemental protein in diets containing the corns. Research conducted at South Dakota State University showed that oats can constitute 60% of the grain portion of growing and finishing swine diets with less supplemental protein and no reduction in pig performance.

The purpose of the research reported herein was to study the value of high protein oats in pig starter diets as well as availability of lysine in the grain. The inclusion of opaque-2, double mutant and waxy

corns in starter diets was also evaluated. Rate of gain, feed consumption and feed efficiency were used as response criteria.

LITERATURE REVIEW

Protein Requirements

The National Research Council (NRC, 1973) lists protein requirements at 22 and 18% for 5- to 10-kg and 10- to 20-kg pigs, respectively. Becker et al. (1954) found that pigs 7 to 28 days old showed no improvement in performance when fed more than 22.4% protein. Rutledge et al. (1961) reported that 3-week-old pigs fed 16, 20, 24 and 28% protein did not differ in weights ($P<.05$) at the end of 5 weeks, but feed/gain tended to decrease as protein increased. There was no difference ($P < .05$) in feed/gain of pigs fed the diets containing more than 20% protein. The 20% protein diet appeared to be more than adequate for the young pig. Using 25-day-old pigs weighing 6.2 to 8.0 kg, Young and Jamison (1970) reported that the performance of pigs was not altered by feeding protein levels above 19.5 percent. Kornegay et al. (1974), however, reported that an 18% corn-soy diet was adequate for the 5-kg pig.

Lowrey et al. (1963) demonstrated that an 18% protein diet in which casein supplied all the protein supported adequate performance when fed to pigs approximately 2 weeks old. Performance of the pigs fed an 18% protein diet in which wheat gluten constituted all of the protein was inferior to that of the casein diet and, in fact, supported no better gains than a 5% gluten diet. Analysis of casein by Bye (1974) showed that the protein consisted of 8.2% lysine, 42.7% of the other essential amino acids and 49.1% non-essential amino acids. Woychik et al. (1961) reported that wheat gluten contained 1.2% lysine, 29.7% other essential amino acids and 69.1% non-essential amino acids. This

demonstrates that the protein quality or relative quantities of amino acids in the protein is of the utmost importance when establishing protein requirements.

Lysine and Tryptophan Requirements

In 1932, Mitchell and Smuts discovered that lysine was the first limiting amino acid in corn, oats and wheat when protein from these grains was fed to growing rats. Lysine was proven to be essential for growth and development of the weanling pig by Mertz et al. (1949). When DL-lysine hydrochloride was included in lysine deficient diets at the rate of 2.0%, deficiency symptoms were alleviated, and growth was supported at the rate of .41 kg per day.

McWard et al. (1959) reported that the lysine requirement of the 13.6 kg weanling pig was dependent on the total protein content of the diet. Response to additional lysine supplied in the form of L-lysine hydrochloride was noted up to .73% lysine in diets containing 12.8% protein and .93% lysine in 21.7% protein diets. Hutchinson et al. (1957a) found that lysine levels above .935% failed to give additional response to weanling pigs fed diets containing 14.25% protein. In further investigations using 15.9-kg pigs, Hutchinson et al. (1957b) reported no significant differences in pig performance when diets contained from .52 to .82% L-lysine at 11.69% protein. Performance was equivalent to those pigs receiving a .6% protein diet. The lysine requirement of weanling pigs increased from .60% in a 10.6% protein diet to approximately 1.2% in a 22% protein diet (Brinegar et al., 1950). The author concluded that the pigs on a high protein diet grew more rapidly and necessitated an

increase in dietary lysine. In 1958, Gupta et al. reported that crystalline L-lysine was 100% available to the animal and that the level of protein in the diet had no effect on the availability of the lysine. Grau and Kamei (1950) also found that the lysine requirement of chicks increased with increasing levels of dietary protein.

Shelton et al. (1950) found that 14.5-kg pigs fed purified diets required .20% DL-tryptophan for normal growth. In 1951, Shelton et al. supplemented 24.5% protein basal diets containing less than .01% tryptophan with .10, .20, .30 and .40% DL-tryptophan. The 14.5-kg pigs used in the trial lost weight when fed the basal diets. When DL-trypotphan was supplied at .1% of the diet the pigs gained .21 kg per day, but this was 50% less than the gain of the pigs fed diets containing .20% DL-tryptophan. No difference in performance of the pigs was noted between diets containing .20, .30 and .40% DL-tryptophan. In 1966 Gallo and Pond reported that .18 to .22% tryptophan in a 20% protein diet was required for normal development of pigs 21 to 45 days old. Baker et al. (1972) reported that 10-kg pigs responded to both D- and L-tryptophan. The author postulated the loss in efficiency for utilization may result from inefficient absorption from the gut or inefficient conversion to L-tryptophan in the tissue.

Energy and Fiber

Energy content of the diet also affects the performance of the weanling pig (Manners and McCrea, 1963). Mitchell et al. (1965) used two levels of metabolizable energy and five levels of lysine in 16% protein diets and found that higher energy diets generally supported

faster gains and better feed efficiency when lysine levels were equal. In 1970, Frobish et al. reported that the addition of 5% fat to diets fed 2- and 3-week-old pigs tended to improve both gain and efficiency. Clawson et al. (1962) also reported that 5% animal fat added to the diet decreased feed intake and increased gains, but energy intake was not reduced. The report concluded that as both energy and protein increased with a constant calorie to protein ratio, feed required per unit of gain was decreased. Clawson (1967) found that both amino acid imbalance and inadequacy depressed caloric intake of 14- to 20-kg weanling pigs. It was also reported that protein level and caloric density influenced daily feed intake independently. Sewell et al. (1961) fed three levels of protein (10, 15, 20%) with two levels of fat (0, 8%) to 3-week-old weanling pigs. The pigs receiving the 20% protein diet with 8% fat had the best gains while those pigs fed the 10 and 15% protein diets showed no growth response to an 8% fat addition. In a second trial, 3-week-old pigs showed a response ($P<.05$) to a 2% fat addition at each protein level with an improvement in feed efficiency as fat levels increased up to 10 percent. There was no difference in pig performance between diets containing 15% protein and 10% fat and diets containing 20% protein and 2% fat.

Whiting and Bezeau (1957) reported that weight of the pig and dietary protein and fiber levels influence the metabolic fecal nitrogen (MFN). Using three levels of fiber (5, 10, 15%) and 14-kg pigs, the authors found an increase in MFN ($P<.01$) as the level of fiber increased with a subsequent lowering of true and apparent digestibility, although biological value of the protein was not affected. An increase in fiber

content of the diet from 5.6 to 12.8% caused a decrease in efficiency and rate of gain of pigs weighing 17.2 kilograms (Cameron, 1960). Pelleting the diets resulted in no response in performance of pigs up to weights of 47.61 kilograms.

Oats in Swine Diets

Although the protein content of oats is generally higher than that of corn (NRC, 1973), the use of oats in swine diets has generally been somewhat limited due to its lower energy and higher fiber content. In 1958, Tang et al. found that lysine was the first limiting amino acid in oats diets and that threonine and methionine also appeared to be more limiting than either histidine or tryptophan. In experiments using rats, diets containing 80% oats supplemented with lysine, methionine and threonine supported gains equal to those diets containing 20% casein. Wahlstrom and Larson (1960) reported that 8-week-old pigs achieved nearly the same performance whether they were fed a diet consisting of 87.5% oats and 10% soybean oil meal or a diet consisting of 87.5% oats supplemented with .1% L-lysine, indicating that except for lysine, oat protein is quite adequate in essential amino acids. Meade, et al. (1966) fed 25-kg pigs 15% protein diets with either 0, 10, 20, 30 or 40% oats and supplemented each of these diets with either .15% L-lysine, .10% DL-methionine or a combination of .15% L-lysine and .10% DL-methionine. The amino acid additions exhibited no effect on pig performance at any of the oats levels. The substitution of up to 30% oats in the diets had no effect on daily gains, but poorer feed efficiency was noted when oats levels in the diets reached 40%. Woodman et al. (1932) reported

that very finely ground oats constituting 40% of the diet had no deleterious effects on gains or feed efficiency while diets containing 40% coarsely ground oats or 40% whole oats in a barley-wheat middlings diet significantly depressed performance of pigs weighing 34 to 63.5 kilograms. But the inclusion of 30 and 70% oats in basal diets consisting of gelatinized corn and soybean meal not only significantly reduced the occurance of ulcer lesions, but did not affect gains when compared to the basal diet or to diets that consisted of 30 or 70% wheat when fed to weanling pigs (Riker et al., 1966).

Wahlstrom and Libal (1975) reported favorable results using oats that contained 16% protein and .66% lysine in that no differences ($P<.05$) were found in performance of pigs fed diets containing up to 60% of the grain portion of the diet as oats. Diets containing this level of oats supported gains of .75 kg per day and a feed efficiency of 3.19 kg per kg of gain in pigs weighing 27 kg to a final weight of 91 kilograms. The inclusion of 60% oats in the grain portion of the diet resulted in a decrease of 43% soybean oil meal in the growing phase (27 to 55 kg) and a decrease of 64% soybean meal during the finishing phase (56 to 91 kg).

Several varieties of oats were chemically analyzed in an attempt to determine protein quality by Robbins et al. (1971). These workers analyzed 289 varieties of oat groats for protein and amino acid content. Lysine values expressed as percent of the protein ranged from 4.8 to 5.2% while protein values ranged from 14.2 to 20.1% demonstrating that the quality of the crude protein remains relatively constant. Maruyama et al. (1975) found that there was little difference in the performance

of pigs fed either 24 or 32-pound test oats, although the feed efficiency of the pigs fed the diets containing the heavier oats was somewhat better.

Corn in Swine Diets

Corn has a high metabolizable energy content (DeGoey and Ewan, 1975). This coupled with its palatability and availability has made corn the major constituent of many practical swine diets. Mitchell and Smuts (1932), Hogan et al. (1955) and Mahan et al. (1973) found that lysine was the first limiting amino acid in corn diets. Lawrence (1972), however, reported that tryptophan was the first limiting amino acid in corn diets and his research supported that of Baker et al. (1969), who found that although tryptophan was the first limiting amino acid, it was only slightly more limiting than lysine. In 1968, Gallo et al. reported that the addition of eleven essential and non-essential amino acids in various combinations did not improve pig performance above that obtained by the addition of .30% L-lysine in combination with .05% DL-tryptophan, and concluded that lysine and tryptophan were first and second limiting amino acids, respectively, for corn diets. These findings were supported by Gallo and Pond (1968) and Clawson and Matrone (1963) who observed no response to lysine supplementation of corn diets unless lysine supplementation was accompanied by tryptophan supplementation.

Lysine Supplementation

Much work has been conducted in supplementing corn-soy diets with lysine. Magruder et al. (1961) found that supplementing 14% protein

diets of 2-week-old weanling pigs with .1% L-lysine supported gains equal to a 16% protein corn-soy diet, although feed efficiency was poorer. Meade et al. (1965) reported that a 16% protein corn-soy diet supplemented to be equal to an 18% protein diet in lysine and methionine supported gains and feed efficiencies in weanling pigs equal to the 18% corn-soy diets. Katz et al. (1973) observed that a 19% corn-soy diet supplemented with .1% L-lysine significantly improved feed efficiency of 9-kg pigs, but there was no improvement in gains. Allee et al. (1973), however, could find no advantage in adding .1% L-lysine to an 18% protein milo-soy diet.

High Lysine Corn

In 1964, Mertz et al. discovered that the mutant opaque-2 gene changed the amino acid composition of corn endosperm. The resultant mutant showed a 60% increase in lysine content. Subsequent feeding trials with rats utilizing the mutant corn (Mertz et al., 1965) have prompted extensive research with opaque-2 corn in swine diets. Mirsa et al. (1972) analyzed 6 different mutant corns and reported that those mutants which have a higher lysine content tend to have increased glutelin content and a corresponding decrease in zein content. Pick and Meade (1970) observed the enhanced nutritional value of opaque-2 corn in trials utilizing 13.5-kg pigs. No differences in pig performance were found when soybean meal supplementation was decreased from 16 to 8% of the diet. In feeding trials utilizing 10- to 13-kg pigs, Cromwell et al. (1967) found that improved performance of the pigs fed the opaque-2 corn was not due to increased lysine content

alone, but probably to a concomitant increase in tryptophan. In 1969, Sihombing et al. found that 13.6-kg pigs fed opaque-2 corn had significantly higher daily gains and better feed efficiency than pigs fed normal corn at each of four levels of protein; 7.9, 11.1, 14.4 and 17.6%. With the results of four trials using weanling pigs, it was reported that 5 to 8% less soybean meal is needed when opaque-2 corn is fed. Moser et al. (1972) reported increases in both gains and efficiency in each of three levels of protein (12, 16, 20%) for pigs fed opaque-2 corn when both opaque-2 and normal corn were fed to 4.1-kg pigs. Wahlstrom and Libal (1973) fed weanling pigs opaque-2 and normal corn either in a complete ground and mixed form or as whole corn with free choice protein supplement provided. Although the pigs consumed no more ($P<.05$) opaque-2 corn than normal corn, the pigs fed the opaque-2 corn free choice consumed less ($P<.025$) supplement than the pigs fed the whole normal corn. Pigs fed whole normal corn tended to overconsume the supplement indicating that amino acids needs may be more important than crude protein requirements. Cromwell et al. (1967) have reported that pigs preferred opaque-2 corn to normal corn because of the softer texture and more favorable balance of amino acids.

Nelson et al. (1965) reported that a second mutant gene, floury-2 also altered the amino acid content of corn endosperm. Analysis of the mutant corn indicated a higher tryptophan content than opaque-2 corn and a lysine content of two times that of normal corn. Maner et al. (1971) found that the performance of weanling pigs fed Colombian floury-2 corn inferior to that of Colombian opaque-2 corn and concluded that lysine

threonine and tryptophan may be less than desirable for normal growth although methionine appeared to be adequate. The addition of lysine and tryptophan to a floury-2 corn diet significantly improved the performance of rats (Pond et al., 1971). The author concluded that the first and second limiting amino acids for floury-2 corn were lysine and tryptophan, respectively. Klein et al. (1971) conducted experiments using weanling pigs fed opaque-2, floury-2 and normal corn diets. Performance of the pigs fed floury-2 was superior to those receiving normal corn, but opaque-2 corn diets supported better performance than either floury-2 or normal corn. Lysine in opaque-2 corn was shown to be more available than lysine from the other corns tested.

MATERIALS AND METHODS

The experiment consisted of three separate trials utilizing 407 crossbred pigs of Duroc, Yorkshire and Hampshire breeding weighing between 7.3 and 10.4 kilograms. The pigs, ranging in age from 4 to 6 weeks, were all farrowed at the South Dakota State University Swine Unit. Each trial consisted of three replicates of eight dietary treatments fed for 28 days.

All male pigs were castrated at approximately 14 days of age. Pigs were weighed periodically from day 28 to allow each replication to begin when pigs averaged approximately 9 kilograms. Each replication was put on experiment separately to insure adequate pig numbers and weight. The pigs were not creep fed and were removed from their dams and placed directly on experimental diets. Experimental animals were randomly assigned to treatment on the basis of weight and ancestry. Sex was not used as a criteria for allotment.

Each group was housed indoors in 2.4 x 3.0 m pens. The floors were solid concrete and wood shavings were used for bedding. Air temperature was maintained at approximately 15 C with supplemental heat provided as needed.

The pigs were weighed weekly and feed was weighed back at the end of the trial to obtain performance data. Each pen was provided with a self-feeder and an automatic waterer. The grain portion of the diets was processed through a conventional hammer mill with a 4.8 mm screen. Vitamin premixes, antibiotics and amino acids were preweighed and mixed with a diluent before being added to the other ingredients in a twin

spiral vertical mixer at the University feed unit. Dehulled soybean meal (48.5% protein) and Dal oats (16.6% protein and .66% lysine) were used in all trials. The opaque-2, double mutant, and waxy corns were all obtained from the Trojan Seed Company. L-lysine supplementation was accomplished by adding L-lysine monohydrochloride which was calculated to contain 78% L-lysine. Amino acid analysis of the grains used in the experiment is shown in Appendix Table 1.

Trial 1. High Protein Oats, Double Mutant Corn and Waxy Corn in Starter Diets.

The first trial was started on April 3, 1974, and was terminated on May 13, 1974. One hundred forty-four pigs averaging 8.9 kg were randomly allotted to eight treatments with three replications per treatment. The treatments were as follows:

Diet 1. Normal corn (18% protein)

Diet 2. Oats (protein equal to diet 1)

Diet 3. Oats (lysine equal to diet 1)

Diet 4. Oats-corn oil (isocaloric and isonitrogenous to diet 1)

Diet 5. Oats (oats replaced corn on an equal weight basis to diet 1)

Diet 6. Normal corn-oats (oats replaced one-half of the corn on weight basis to diet 1)

Diet 7. Double mutant corn (16.5% protein, lysine equal to diet 1)

Diet 8. Waxy corn (protein equal to diet 1)

The composition of the diets is shown in Table 1. The corn oil and corn starch used in diet 4 were calculated to contain 7300 and 3125 kcal of metabolizable energy per kilogram.

Trial 2. Lysine Availability of Oats and the Value of Double Mutant Corn in Starter Diets.

The second trial was conducted from June 28, 1974, through August 9, 1974. One hundred forty-four pigs averaging 9.1 kg were randomly assigned to eight dietary treatments with three replications per treatment. The experimental treatments were as follows:

Diet 1. Normal corn plus .15% L-lysine

Diet 2. 10% oats (replacing corn) plus .11% L-lysine

Diet 3. 20% oats (replacing corn) plus .07% L-lysine

Diet 4. 40% oats (replacing corn)

Diet 5. Double mutant corn

Diet 6. 20% oats (replacing double mutant corn)

Diet 7. 40% oats (replacing double mutant corn)

Diet 8. Waxy corn plus .15% L-lysine

The composition of the diets used in this trial is shown in Table 2. Diets 1, 2, 3, 4 and 8 were calculated to be equal in lysine content. Total energy of the diets decreased and protein increased with increasing levels of oats substitution.

Trial 3. Lysine Availability of High Protein Oats and Its Value in Starter Diets.

Trial 3 was initiated on September 30, 1974, and was terminated on November 12, 1974. The trial, which consisted of three replications

TABLE 2. PERCENTAGE COMPOSITION OF DIETS. TRIAL 2 (PERCENT)

Ingredients	Diet 1 Corn-soy + .15% lysine	2 10% oats + .11% lysine	3 20% oats + .07% lysine	4 40% oats	5 Double mutant corn-soy	6 20% oats	7 40% oats	8 Waxy corn + .15% lysine
Corn	76.91	66.96	57.01	37.1	--	--	--	--
Oats	--	10.0	20.0	40.0	--	20.0	40.0	--
Double mutant corn	--	--	--	--	77.1	57.1	37.1	--
Waxy corn	--	--	--	--	--	--	--	76.91
Soybean meal, 48.5%	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
TM salt	.4	.4	.4	.4	.4	.4	.4	.4
Dicalcium	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Limestone	.7	.7	.7	.7	.7	.7	.7	.7
Premix[a]	.4	.4	.4	.4	.4	.4	.4	.4
L-lysine monohydrochloride	.19	.14	.09	--	--	--	--	.19
Calculated content, %								
Protein	17.2	17.7	18.4	19.8	17.0	17.8	19.8	17.2
Lysine	.95	.95	.95	.96	.89	.94	1.00	.95

[a]See table 1.

of eight treatments, utilized 120 pigs averaging 9.1 kilograms. The treatments for trial 3 were as follows:

Diet 1. Normal corn plus starch plus .12% L-lysine (.8% lysine)

Diet 2. Normal corn (.8% lysine)

Diet 3. 20% oats (replacing corn) (.8% lysine)

Diet 4. 40% oats (replacing corn) (.8% lysine)

Diet 5. Normal corn plus .15% L-lysine (.95% lysine)

Diet 6. 20% oats (replacing corn) plus .07% L-lysine (.95% lysine)

Diet 7. 40% oats (replacing corn) (.95% lysine)

Diet 8. Opaque-2 corn (.95% lysine)

The composition of the diets used in Trial 3 is shown in Table 3. Diets 1, 2, 3 and 4 were calculated to be equal in lysine content (.8% of the diets), but protein content of the diets increased and energy level decreased with increasing levels of oats substitution. Lysine levels of diets 5, 6, 7 and 8 were also calculated to be equal (.95% of the diet), but protein and fiber increased with increasing levels of oats substitution.

Necropsy examination by the South Dakota State University Animal Disease Research and Diagnostic Laboratory of the one pig that died supported a diagnosis of acute hemolytic E. coli gastroenteritis of weaned pigs. Feed consumption was corrected for death loss by subtracting an average value of the feed consumed to time of death.

The parameters used to evaluate the various diets were average daily gain, feed efficiency and feed consumption. The data collected were analyzed statistically by least squares analysis of variance as

TABLE 3. PERCENTAGE COMPOSITION OF DIETS. TRIAL 3 (PERCENT)

Ingredients	Diet 1 Corn-soy-starch + .12% lysine	2 Corn-soy	3 20% oats	4 40% oats	5 Corn-soy + .15% lysine	6 20% oats + .07% lysine	7 40% oats	8 Opaque-2 corn-soy
Corn	60.45	77.1	60.4	42.6	76.91	57.01	37.1	--
Oats	--	--	20.0	40.0	--	20.0	40.0	--
Opaque-2 corn	--	--	--	--	--	--	--	77.1
Corn starch	19.9	--	--	--	--	--	--	--
Soybean meal, 48.5%	16.6	20.0	16.7	14.5	20.0	20.0	20.0	20.0
TM salt	.4	.4	.4	.4	.4	.4	.4	.4
Dicalcium	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Limestone	.7	.7	.7	.7	.7	.7	.7	.7
Premix[a]	.4	.4	.4	.4	.4	.4	.4	.4
L-lysine monohydrochloride	.15	--	--	--	.19	.09	--	--
Calculated content, %								
Protein	13.9	17.0	17.2	17.7	17.2	18.5	18.9	17.4
Lysine	.79	.80	.79	.81	.95	.95	.96	.95

[a]See table 1.

outlined by Steel and Torrie (1960). Tukey's "w" procedure was used to determine significant differences between treatments when significant differences were obtained within trials.

RESULTS AND DISCUSSION

Trial 1. Effects of Feeding High Protein Oats, Double Mutant Corn and Waxy Corn in Starter Diets.

The data from the first trial are summarized in Tables 4 and 5. The statistical analyses for this trial are presented in Tables 6 and 7.

Pigs fed the double mutant corn-soy diet (diet 7) had average final weights of 22.3 kg which was greater ($P<.05$) than the average final weights of 18.1, 17.9, 20.8 and 20.6 kg of the pigs fed diets containing more than 40% oats, diets 2, 3, 4 and 5, respectively. Pigs fed diets 2 and 3 which contained 90.7 and 86.6% oats, respectively, had final weights significantly less ($P<.05$) than the average final weights of all other treatments.

The pigs receiving the double mutant corn-soy diet (diet 7) exhibited the highest daily gains of all treatment groups at the end of 7, 14, 21 and 28 days. During the first 7 days, this group together with the pigs fed the control diet (diet 1), gained faster ($P<.05$) than any of the other treatment groups and pigs fed diet 6, equal parts corn and oats, gained faster ($P<.05$) than pigs receiving diets containing oats as the only cereal grain, diets 2, 3, 4 and 5. At the end of the trial, however, only pigs fed diets 2 and 3 had slower gains ($P<.05$) than any of the other diets.

Table 5 shows that the pigs receiving diets 2 and 3 which contained the highest amounts of oats, had consistantly poorer ($P<.05$) weekly average daily gains during weeks 2, 3 and 4 than the other treatments.

TABLE 4. EFFECT OF FEEDING HIGH PROTEIN GRAINS. TRIAL 1.
LEAST SQUARE MEANS

	Diet							
	1	2	3	4	5	6	7	8
	Normal corn-soy control	Oats-soy	Oats-soy Lysine equal to diet 1	Oats-soy Energy equal to diet 1	Sub oats for corn	One-half oats one-half corn-soy	Double mutant corn-soy	Waxy corn-soy
Number of Pigs	18	18	18	18	18	18	18	18
Avg Initial Wt, kg	8.9	8.9	8.9	9.0	8.9	9.0	8.9	8.9
Avg Final Wt, kg[a]	21.0	18.1	17.9	20.8	20.6	21.2	22.3	21.4
Avg daily gain, kg								
7 days[b]	.16	.07	.10	.09	.08	.13	.17	.12
14 days[c]	.26	.18	.15	.22	.21	.23	.30	.25
21 days[d]	.35	.25	.24	.34	.34	.35	.40	.36
28 days[e]	.43	.32	.32	.42	.42	.44	.48	.45
Avg feed/gain[f]	2.22	2.93	2.73	2.46	2.34	2.04	2.08	2.03
Avg feed Consumption/ day, kg	.91	.92	.82	1.01	.96	.87	.97	.87

[a]Diet 7 heavier than 2, 3, 4, 5 (P<.05). Diets 2 and 3 lighter than 1, 4, 5, 6, 7, 8 (P<.05).
[b]Diets 1 and 7 greater than 2, 3, 4, 5, 6, 8 (P<.05). Diet 6 greater than 2, 3, 4, 5 (P<.05). Diet 8 greater than 2, 4, 5 (P<.05). Diet 3 greater than 2 (P<.05).
[c]Diets 1, 7 and 8 greater than 3 (P<.05). Diet 7 greater than 2 (P<.05).
[d]Diets 1, 4, 5, 6, 7, 8 greater than 2 and 3 (P<.05).
[e]Diets 1, 4, 5, 6, 7, 8 greater than 2 and 3 (P<.05).
[f]Diet 8 less than 2, 3 (P<.05). Diets 1, 6 and 7 less than 2 (P<.05).

TABLE 5. WEEKLY AVERAGE DAILY GAINS. TRIAL 1
LEAST SQUARE MEANS

	Diet							
	1	2	3	4	5	6	7	8
	Normal corn-soy control	Oats-soy	Oats-soy Lysine equal to diet 1	Oats-soy Energy equal to diet 1	Sub oats for corn	One-half oats one-half corn-soy	Double mutant corn-soy	Waxy corn-soy
Average daily gain, kg								
7 days[a]	.16	.07	.10	.09	.08	.13	.17	.12
7-14 days[b]	.36	.28	.21	.36	.34	.34	.43	.36
14-21 days[c]	.52	.41	.43	.56	.59	.62	.62	.60
21-28 days[d]	.67	.55	.54	.64	.66	.68	.70	.70

[a]Diets 1 and 7 greater than 2, 3, 4, 5, 6, 8 ($P<.05$). Diet 6 greater than 2, 3, 4, 5 ($P<.05$). Diet 8 greater than 2, 4, 5 ($P<.05$). Diet 3 greater than 2 ($P<.05$).

[b]Diet 7 greater than 2 and 3 ($P<.05$). Diets 1, 4, 5, 6, 8 greater than 3 ($P<.05$).

[c]Diet 6 and 7 greater than 1, 2, 3 ($P<.05$). Diets 4, 5, 8 greater than 2 and 3 ($P<.05$). Diet 1 greater than 2 ($P<.05$).

[d]Diets 7 and 8 greater than 2 and 3 ($P<.05$). Diet 6 greater than 3 ($P<.05$).

TABLE 6. ANALYSIS OF VARIANCE FOR FINAL WEIGHTS AND AVERAGE DAILY GAINS. TRIAL 1

Source	df	Mean Squares: Final weight	ADG 7 days	ADG 14 days	ADG 21 days	ADG 28 days	ADG 2nd week	ADG 3rd week	ADG 4th week
Total	144								
Treatment (T)	7	46.3557**	.0258*	.0390**	.0509**	.0591	.0766**	.1269**	.0738**
Replicate (R)	2	1.7719	.0693**	.0474**	.0275**	.0096	.0251	.0068	.0307*
T x R	14	3.2242	.0083	.0056	.0035	.0037	.0113	.0078	.0137

*P<.05
**P<.01

TABLE 7. ANALYSIS OF VARIANCE FOR FEED CONSUMPTION AND FEED EFFICIENCY. TRIAL 1

Source	df	Mean Squares: Feed Consumption	Feed Efficiency
Total	24		
Treatment	7	.0111	.3379**
Replicate	2	.0010	.0115
Remainder	14	.0100	.0605

**P<.01

During this period the gains of the pigs fed oats diets with equal energy to the control diet (diet 4) and in which oats was substituted for corn (diet 5) were similar to and not different ($P<.05$) than gains of pigs receiving corn in their diets. Pigs fed diets 4 and 5 gained significantly faster than pigs fed diet 3 during the second week and faster ($P<.05$) than those fed diets 2 and 3 during the third week. The difference in rate of gain was not significant the last week of the trial. Gains of pigs fed waxy corn (diet 8) were similar to those fed normal or double mutant corn except for the first week when they were significantly less.

The patterns of the weekly average daily gains may be an indication that the newly weaned pigs had some difficulty adjusting to the oats diets, but once the adjustment was made, pigs fed diet 5 in which oats was substituted for corn gained as well as pigs fed the control diet (diet 1). Diet 5 contained the same amount of soybean meal as diet 1, but the oats content would have increased both protein and fiber content with a subsequent decrease in energy. Although the lowered energy content may explain the lower gains of the pigs fed diet 5 during the first seven days, when the energy of the oats diets was equalized (diet 4), gains of pigs fed diet 4 were also slower than the pigs fed diet 1. This gives further indication that adjustment of the pigs to the diets may have been the reason for the slower 7 day gains rather than an improper balance of nutrients.

Woodman *et al*. (1932) and Meade *et al*. (1966) found that the inclusion of more than 40% oats in swine diets suppressed gains.

However, cummulative average daily gains of the pigs in the trial reported herein generally support the reports of Tang et al. (1958) working with rats, and Riker et al. (1966) working with pigs, who found that oats substitution of 70% of the diet did not affect gains.

The increased fiber content and lower energy content of diets 2 and 3 when compared to the other diets were most probably the contributing factors to the poor performance of the pigs fed these diets. Cameron (1960) found that increasing levels of fiber in the diets resulted in depressed gains and Boenker et al. (1969) found that increasing levels of fiber resulted in a decrease in nitrogen digestibility. Reducing the fiber content and increasing the energy content of the diets by the addition of corn starch, corn oil, soybean meal or corn (diets 4, 5 and 6) significantly increased the gains of the pigs fed these diets when compared to diets 2 and 3.

The lower energy content of diets containing more than 85% oats (diets 2 and 3) is reflected in the poorer feed efficiencies of the pigs fed these diets. Feed to gain ratios of 2.93 and 2.73 for pigs fed diets 2 and 3, respectively, were higher ($P<.05$) than for pigs fed the waxy corn diet. Pigs fed diets 1, 6 and 7 also required less feed per unit of gain ($P<.05$) than pigs fed diet 2. Feed efficiency of pigs fed the waxy corn diet (diet 8), the one half corn-one half oats diet (diet 6) and the double mutant corn diet (diet 7) were 2.03, 2.04 and 2.08, respectively, indicating that these diets were apparently well balanced and had very desirable amino acid-energy ratios. Although feed/gain of pigs fed the control diet (diet 1), the oats plus energy diet (diet 4) and the diet in which oats was substituted for corn (diet 5) was greater

than that of pigs fed diets 6, 7 or 8, the difference was not significant ($P<.05$).

There were no differences ($P<.05$) in daily feed consumption between any of the treatments. Average daily feed consumption ranged from .82 kg for pigs fed diet 3 to 1.01 kg for pigs fed diet 4. Although Asplund *et al*. (1960) noted a decrease in consumption of diets containing corn oil, no such effect was noted here. In fact, the diet containing corn oil had the highest consumption rate. Even though the diets containing the larger amounts of oats had a somewhat coarse appearance and were quite bulky, the animals tended to consume these diets as well as the corn diets.

Excellent performance was obtained when pigs were fed the double mutant corn-soy diet which contained the lowest percentage of protein (16.5%). This indicates that amino acid balance or protein quality is of more importance than protein content of the diet *per se*.

Spraque *et al*. (1943) reported that corn homozygous for the recessive waxy gene contained only amylopectin in the starch portion of the endosperm while corn without the recessive gene contained approximately 20% amylose and 80% amylopectin in the starch fraction of the endosperm. Boundy *et al*. (1967) found that the total protein content of waxy corn was not different from normal corn, but more of the protein in the waxy corn was contained in globulin and glutelin with less protein as zein.

The pigs fed the diet containing waxy corn (diet 8) had gains and final weights similar to those animals receiving the control diet. Feed per gain of the pigs fed the waxy corn diet were the most desirable of

any of the treatment groups although not significantly different from the control diet. Performance of the pigs fed diet 8 indicates that the waxy corn contains sufficient energy to support adequate gains and very desirable feed efficiency of the weanling pig.

Trial 2: Lysine Availability of High Protein Oats and the Value of Double Mutant Corn and Waxy Corn in Starter Diets.

The summarized performance data for trial 2 are shown in Tables 8 and 9. The statistical data for the trial are shown in Tables 10 and 11.

There were no differences ($P<.05$) in either final weights or daily gains of the pigs fed the various diets. Final weights ranged from 19.6 kg for the pigs fed the double mutant corn (diet 5) to 18.2 kg for the pigs receiving the corn-soy diet with .15% L-lysine added (diet 1). Average daily gains ranged from .33 to .38 kg per day.

The feed to gain ratio of 2.96 of pigs fed diet 7, in which oats constituted 40% of the diet replacing double mutant corn, was higher ($P<.05$) than the 2.08 feed to gain ratio of pigs fed diet 5, in which double mutant corn constituted all of the grain. Because of the bulky nature of the 40% oats diet, adjustment of the feeders during the early portion of the trial was difficult. Excess feed wastage by one of the pens receiving diet 7 contributed to the poorer feed efficiency. Pigs fed diet 7 also consumed the most feed per day (.98 kg), in part due to the excessive feed wastage mentioned above, while pigs fed diet 1 consumed the least feed per day (.75 kg). There were no significant differences in daily feed consumption among the dietary treatments.

TABLE 8. EFFECT OF HIGH PROTEIN GRAIN AND LYSINE SUPPLEMENTATION. TRIAL 2
LEAST SQUARES MEANS

	Diet							
	1	2	3	4	5	6	7	8
	Corn-soy + .15% lysine	10% Oats + .11% lysine	20% Oats + .07% lysine	40% oats	Double Mutant corn	20% oats	40% oats	Waxy Corn + .15% lysine
Number of pigs[a]	18	18	18	18	18	17	18	18
Avg initial wt, kg	9.0	9.0	9.1	9.1	9.1	9.1	9.1	9.1
Avg final wt, kg	18.2	18.5	18.4	19.0	19.6	18.9	18.4	19.0
Avg daily gain, kg								
7 days	.05	.08	.03	.07	.07	.09	.03	.10
14 days	.17	.20	.20	.20	.21	.19	.21	.20
21 days	.25	.28	.27	.28	.30	.27	.26	.27
28 days	.34	.34	.33	.36	.38	.35	.34	.35
Avg feed/gain[b]	2.18	2.26	2.53	2.29	2.08	2.21	2.96	2.38
Avg feed consumption/day, kg	.75	.76	.84	.79	.78	.78	.98	.86

[a]One pig died, data not included.
[b]Diet 7 greater than 5 ($P<.05$).

TABLE 9. WEEKLY AVERAGE DAILY GAINS. TRIAL 2
LEAST SQUARE MEANS

	Diet							
	1	2	3	4	5	6	7	8
	Corn-soy + .15% lysine	10% oats + .11% lysine	20% oats + .07% lysine	40% oats	Double Mutant corn	20% oats	40% oats	Waxy Corn + .15% lysine
Avg daily gain, kg								
1-7 days	.05	.08	.03	.07	.07	.09	.03	.10
7-14 days	.28	.32	.37	.33	.36	.31	.38	.31
14-21 days	.41	.43	.41	.46	.49	.40	.38	.40
21-28 days	.56	.51	.53	.56	.60	.62	.56	.61

TABLE 10. ANALYSIS OF VARIANCE FOR FINAL WEIGHT AND AVERAGE DAILY GAIN. TRIAL 2

Source	df	Mean Squares							
		Final weight	ADG 7 days	ADG 14 days	ADG 21 days	ADG 28 days	ADG 2nd week	ADG 3rd week	ADG 4th week
Total	143								
Treatment (T)	7	3.5808	.0113	.0030	.0038	.0035	.0223	.0221	.0280
Replicate (R)	2	11.2093	.0333*	.0094	.0168	.0043	.0196	.1687**	.0060
T x R	14	8.3741	.0205	.0151	.0117	.0143	.0133	.0179	.0325

*P<.05
**P<.01

TABLE 11. ANALYSIS OF VARIANCE FOR FEED CONSUMPTION AND FEED EFFICIENCY. TRIAL 2

Source	df	Mean Squares	
		Feed Consumption	Feed Efficiency
Total	24		
Treatment	7	.0178	.2874*
Replicate	2	.0004	.0287
Remainder	14	.0139	.1009

*P<.05

Feed consumption and gains were less for this trial than Trial 1. The lower gains in trial 2 appear to be due to the poorer start of the pigs as reflected by the slow gains during the first week. It should also be noted that gains for the 14- to 21-day period were lower than those in Trial 1. Trial 2 was conducted during the warmer months of June and July. It is possible that the warmer temperatures could have had a deleterious effect on gain and feed consumption.

Diets 1, 2, 3 and 4 were all formulated to contain equal levels of lysine (.95%). Diets 1, 2 and 3 were supplemented with L-lysine hydrochloride which was found to be highly available by Gupta et al. (1958). The 40% oats diet (diet 4) had a higher percentage of the total dietary lysine provided by the oat protein. The performance of the pigs fed this diet indicated the lysine in the Dal oats used in this trial was highly available. In fact, gain and feed efficiency of the pigs fed diet 4 were equal to or superior to that of the pigs fed the 10 and 20% oats diets supplemented with L-lysine.

As in the previous trial, the pigs receiving the double mutant corn (diet 5) exhibited the best gains and feed efficiency even though this diet was slightly lower in crude protein and lysine than other diets, indicating a very desirable amino acid balance and energy protein ratios.

The pigs fed the waxy corn diet which contained a similar level of protein and lysine to the control diet (diet 1) had gains equal to the normal corn diet (diet 1) and slightly less than the double mutant corn diet (diet 5), although not significantly different. The feed to

gain ratio of the pigs fed diet 8 was greater than either diet 1 or diet 5, but this difference was not significant ($P<.05$).

Trial 3: Lysine Availability of High Protein Oats and Opaque-2 Corn and Their Value in Starter Diets.

The performance data collected from Trial 3 are summarized in Tables 12 and 13. The statistical analysis of the performance parameters are shown on Tables 14 and 15.

The diets in Trial 3 can be generally divided into two groups based on lysine content. Diets 1, 2, 3 and 4 contained approximately .80% lysine with protein ranging from 13.9 to 17.7% while diets 5, 6, 7 and 8 contained approximately .95% lysine with a protein range of 17.2 to 18.9%.

There were no differences ($P<.05$) in either final weight or rate of gain of the pigs in this trial. Final weights and average daily gains ranged from 20.5 and .41 kg for pigs fed the 18% protein corn-soy diet (diet 2) to 18.1 and .32 kg for pigs fed the 40% oats diet (diet 4).

Feed to gain ratios of pigs fed diets containing .80% lysine were 2.58, 2.30, 2.74 and 2.67 for diets 1, 2, 3 and 4, respectively, When diets contained .95% lysine, feed to gain ratios were 2.02, 2.08, 2.14 and 2.08 for diets 5, 6, 7 and 8, respectively. The feed efficiencies of pigs fed diets 3 and 4 were poorer ($P<.05$) than that of pigs receiving diet 5. Single degree of freedom comparisons between diets containing .80% lysine and .95% lysine showed a highly significant difference in the feed efficiency and feed consumption of pigs fed these

TABLE 12. EFFECTS OF HIGH PROTEIN GRAIN AND LYSINE SUPPLEMENTATION. TRIAL 3
LEAST SQUARE MEANS

	Diet							
	1 Corn-soy starch + .12% lysine	2 Corn-soy	3 20% oats	4 40% oats	5 Corn-soy + .15% lysine	6 20% oats + .07% lysine	7 40% oats	8 Opaque-2 corn-soy
Number of Pigs	15	15	15	15	15	15	15	15
Avg initial wt, kg	9.1	9.1	9.1	9.1	9.2	9.0	9.1	9.1
Avg final wt, kg	19.1	20.5	19.7	18.1	19.5	20.0	20.1	20.4
Avg daily gain, kg								
7 days	.14	.10	.13	.06	.06	.06	.11	.09
14 days	.23	.25	.23	.19	.21	.23	.24	.23
21 days	.29	.33	.30	.27	.29	.31	.33	.30
28 days	.36	.41	.38	.32	.37	.39	.39	.40
Avg feed/gain[a]	2.58	2.30	2.74	2.67	2.02	2.08	2.14	2.08
Avg feed consumption/day, kg[b]	.91	.93	1.03	.85	.74	.81	.85	.83

[a]Diets 3 and 4 greater than 5 ($P<.05$).
[b]Diet 3 greater than 5, 6, 8 ($P<.05$).

TABLE 13. WEEKLY AVERAGE DAILY GAINS. TRIAL 3
LEAST SQUARE MEANS

	Diet							
	1 Corn-soy starch + .12% lysine	2 Corn-soy	3 20% oats	4 40% oats	5 Corn-soy + .15% lysine	6 20% oats + .07% lysine	7 40% oats	8 Opaque-2 corn-soy
Avg daily gain, kg								
1-7 days	.14	.10	.13	.06	.06	.06	.11	.09
7-14 days	.32	.39	.34	.32	.37	.39	.34	.37
14-21 days	.42	.50	.45	.43	.47	.48	.50	.44
21-28 days	.54	.62	.60	.48	.60	.63	.59	.70

[a]Diet 8 greater than 4 ($P<.05$).

TABLE 14. ANALYSIS OF VARIANCE FOR FINAL WEIGHT AND AVERAGE DAILY GAIN. TRIAL 3

Source	df	Mean Squares							
		Final weight	ADG 7 days	ADG 14 days	ADG 21 days	ADG 28 days	ADG 2nd week	ADG 3rd week	ADG 4th week
Total	120								
Treatment (T)	7	8.9476	.0153	.0054	.0055	.0117	.0136	.0144	.0663**
Replicate (R)	2	10.5730	.3071**	.0262	.0654**	.0106	.5338**	1.0519**	.3261**
T x R	14	8.6618	.0157	.0166	.0150	.0110	.0226	.0276	.0218

TABLE 15. ANALYSIS OF VARIANCE FOR FEED CONSUMPTION AND FEED EFFICIENCY. TRIAL 3

Source	df	Mean Squares	
		Feed Consumption	Feed Efficiency
Total	24		
Treatment	7	.0224*	.2612**
1, 2, 3, 4 vs. 5, 6, 7, 8	1	.0900**	1.5251**
Replicate	2	.0001	.0847
Remainder	14	.0062	.0511

*P<.05
**P<.01

diets. Least squares analysis showed no difference ($P<.05$) in gains. Results of this trial support the finding of Wahlstrom and Libal (1974) and Brown et al. (1973) who found that the lysine needed to support optimum feed efficiency of the growing pig was greater than that needed for optimum gains.

Performance of pigs fed diets 4 and 7, both of which contained 40% oats, was not significantly different, although pigs fed diet 7 gained 18% faster and required 20% less feed per gain. Feed consumption of the two diets was very similar. Diet 7 contained more soybean meal and less corn and therefore higher protein and lysine levels than diet 4. Energy and fiber content of the diets were essentially the same since the metabolizable energy and fiber values for corn and soybean are nearly equal. This would appear to be further evidence that lysine values of .80% were not adequate to support maximum performance of young weaned pigs.

Gains of pigs fed diet 1, which contained 13.9% protein and .79% lysine were not significantly different than those pigs fed diets of 17.0% crude protein and .80% lysine (diet 2) or 17.2% protein and .95% lysine (diet 5). Although average daily gain was higher for diet 2, the difference was not significant. These results tend to support the work of Bowland (1962) who found that a 13.6% protein diet with .74% lysine fed to weanling pigs supported gains and feed efficiency equal to a 16% protein diet with .72% lysine. It is very apparent that amino acid balance and energy are more important to adequate performance than is protein content alone.

Pigs fed the opaque-2 corn-soy diet (diet 8) gained as well as pigs fed the normal corn-soy diet with .15% L-lysine added. Final weights and feed efficiency of the pigs receiving diet 8 were no different ($P<.05$) than those of pigs receiving any of the diets with supplemental lysine. The value of the higher lysine in opaque-2 corn used in the trial appears to be highly available to the young pig.

Pigs fed diets 5, 6 and 8 consumed .74, .81 and .83 kg of feed per day, respectively, which was less ($P<.05$) than the 1.03 kg of feed consumed per day by the pigs fed diet 3. The oats diets were all consumed quite readily and gave no indication of unpalatability.

SUMMARY

A total of 407 crossbred pigs 4 to 6 weeks old weighing 7.3 to 10.4 kg were utilized in the experiment which consisted of three separate trials. Each of the trials had three replicates of eight dietary treatments and were conducted for 28 days. Feed and water were provided ad libitum.

Dal oats, opaque-2, double mutant, waxy and normal corns were used as sources of cereal grains in the diets. Lysine supplementation was accomplished using L-lysine hydrochloride and dehulled soybean meal (48.5% protein) was used as a protein supplement.

In Trial 1, pigs fed diets which contained 90.7 and 86.6% oats gained significantly slower and were significantly lighter at the end of the trial than pigs fed normal, waxy and double mutant corn-soy diets or diets of 37.2, 43 or 74.5% oats. Daily gain of the pigs fed the high level of oats was .32 kg while daily gains for the other groups ranged from .42 to .48 kilograms. Pigs fed the double mutant corn-soy diet exhibited the fastest gains (.48 kg) and were significantly heavier at the end of the trial than pigs fed the oats-soy diet with energy equal to the control diet (43% oats) or those pigs fed the diet in which oats substituted for corn (74.5% oats).

Pigs fed the waxy corn-soy diet had a feed to gain ratio of 2.03 which was lower ($P<.05$) than the feed/gain of the pigs fed the two diets containing the greatest amount of oats. Pigs fed diets containing 90% oats required more ($P<.05$) feed/gain (2.93) than did those pigs

fed the 18% protein control diet, the one half corn-one half oats diet or the double mutant corn diet which had feed efficiencies of 2.22, 2.04 and 2.08, respectively.

There were no significant differences in either final weights or average daily gain of the pigs fed the various diets in Trial 2. Final weights ranged from 19.6 kg for pigs fed the double mutant corn-soy diet to 18.2 kg for pigs fed the normal corn-soy plus .15% L-lysine diet. Average daily gain ranged from .38 kg for pigs fed double mutant corn to .33 kg for pigs receiving normal corn and 20% oats plus .07% L-lyine. Feed/gain was 2.08 for the pigs fed the double mutant corn diet and was better ($P<.05$) than the feed efficiency of pigs fed double mutant corn and 40% oats, although excess feed wastage was a contributing factor to the poorer feed efficiency of the pigs fed the latter diet.

Final weights of the pigs fed the various diets in Trial 3 ranged from 18.1 kg for pigs fed a 40% oats diet containing .80% lysine to 20.5 kg for pigs receiving a normal corn-soy diet with .80% lysine; however, the differences were not significant. No differences ($P<.05$) were observed in daily gains among the various treatments.

Significant differences in feed efficiency were noted between pigs fed diets containing 20% and 40% oats with .80% lysine and pigs receiving the normal corn-soy diet.15% supplemental L-lysine diet which contained .95% lysine. The normal corn-soy diet supplemented with .15% L-lysine, the 20% oats diet supplemented with .07% L-lysine and the opaque-2 corn diet all contained .95% lysine and supported

better ($P<.05$) feed efficiencies than the .80% lysine diet containing 20% oats.

The results of these trials indicate that the high protein oats can effectively replace up to 50% of the corn in practical pig starter diets without affecting gains, although feed/gain tends to be somewhat greater. Because of their higher lysine and adequate energy content, opaque-2 and double mutant corn can support excellent performance in starter diets when properly supplemented. As with the high protein oats, the high lysine corns require less supplemental protein in starter diets than diets based on normal corn as the cereal grain.

Waxy corn appears to have adequate energy content for weanling pigs and is equal in value to normal corn in pig starter diets. Performance of pigs in Trial 3 indicated that the lysine requirement of the 10 kg pig is in excess of .80 percent.

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APPENDIX

APPENDIX TABLE 1. AMINO ACID ANALYSES OF GRAINS USED IN TRIALS 1, 2 and 3.

Grain	Opaque-2 Corn	Waxy Corn	Double Mutant Corn	Normal Corn	Dal Oats
Amino Acid, %					
Aspartic acid	.95	.68	.76	.64	1.18
Threonine	.38	.39	.39	.37	.51
Serine	.96	.50	.49	.48	.69
Glutamic acid	1.53	2.01	1.92	1.72	3.31
Proline	.87	.99	.82	.92	.88
Glycine	.48	.38	.44	.35	.70
Alanine	.65	.85	.79	.70	.68
Cystine	.14	.18	.18	.18	.30
Valine	.48	.48	.54	.47	.82
Methionine	.21	.22	.24	.21	.27
Isoleucine	.33	.39	.38	.35	.61
Leucine	.83	1.37	1.14	1.25	.87
Tyrosine	.33	.38	.31	.32	.53
Phenylalanine	.47	.54	.55	.48	.75
Histidine	.29	.24	.30	.26	.70
Lysine	.42	.31	.38	.27	.66
Ammonia	.14	.15	.13	.12	----
Arginine	.44	.43	.43	.38	1.25