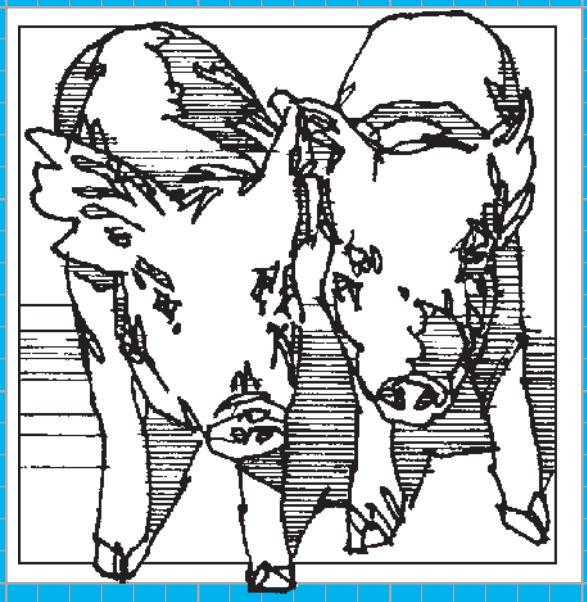


K-STATE
Kansas State University

# SWINE DAY 1998

REPORT OF PROGRESS 819, KANSAS STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

## FOREWORD

It is with great pleasure that we present to you the 1998 Swine Industry Day Report of Progress. This report contains updates and summaries of applied and basic research conducted at Kansas State University during the past year. We hope that the information will be of benefit, as we attempt to meet the needs of the Kansas swine industry.

Editors, 1998 Swine Day Report of Progress,

Bob Goodband Mike Tokach Steve Dritz

## ABBREVIATIONS USED IN THIS REPORT

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ADG | = | average daily gain | g | = | gram(s) | ml | = | cc (cubic centimeters) |
| ADFI | = | average daily feed intake | gal | = | gallon(s) | | | |
| | | | GE | = | gross energy | mo | = | month(s) |
| avg | = | average | h | = | hour(s) | $\mu$g | = | microgram(s) |
| BW | = | body weight | in | = | inch(es) | | = | .001 mg |
| cm | = | centimeter(s) | IU | = | international unit(s) | N | = | nitrogen |
| CP | = | crude protein | | | | ng | = | nanogram(s) |
| CV | = | coefficient of variation | kg | = | kilogram(s) | | = | .001 $\mu$g |
| | | | Kcal | = | kilocalorie(s) | no. | = | number |
| cwt | = | 100 lb | lb | = | pound(s) | ppm | = | parts per million |
| d | = | day(s) | Mcal | = | megacalorie(s) | sec | = | second(s) |
| DM | = | dry matter | ME | = | metabolizable energy | wk | = | week(s) |
| °F | = | Fahrenheit | | | | wt | = | weight(s) |
| F/G | = | feed efficiency | mEq | = | milliequivalent(s) | yr | = | year(s) |
| ft | = | foot(feet) | min | = | minute(s) | | | |
| $ft^2$ | = | square foot(feet) | mg | = | milligram(s) | | | |

## KSU VITAMIN AND TRACE MINERAL PREMIXES

Diets listed in this report contain the following vitamin and trace mineral premixes unless otherwise specified.

**Trace mineral premix**: each lb of premix contains 12 g Mn, 50 g Fe, 50 g Zn, 5 g Cu, 90 mg I, and 90 mg Se.

**Vitamin premix**: each lb of premix contains vitamin A, 2,000,000 IU; vitamin $D_3$, 300,000 IU; vitamin E, 8,000 IU; menadione, 800 mg; riboflavin, 1,800 mg; pantothenic acid, 6,000 mg; niacin, 10,000 mg; and vitamin $B_{12}$, 8 mg.

**Sow add pack**: each lb of premix contains choline, 100,000 mg; biotin, 40 mg; folic acid, 300 mg; and pyridoxine, 2,750 mg.

## NOTICE

Trade names are used to identify products. No endorsement is intended, nor is any criticism implied of similar products not named.

Some of the research reported here was carried out under special FDA clearances that apply only to investigational uses at approved research institutions. Materials that require FDA clearances may be used in the field only at the levels and for the use specified in that clearance.

## CONTENTS

*Swine Day 1998*

# PHOSPHORUS-REDUCING TECHNOLOGIES IN SWINE PRODUCTION

*M. A. Boland [1], K. A. Foster [1], and P. V. Preckel [1]*

## Summary

Soil phosphorus levels have increased as swine production has become concentrated. Phosphorus-based manure management regulations for land application have been proposed by policy makers. The objective of this research was to determine benefits/costs of adopting phytase for reducing phosphorus. Results were derived using different manure storage and application systems. Although phytase was a least-cost ingredient, it became profitable when producers were constrained by land. Land requirements were 2 to 5 times greater under a phosphorus application regulation than a nitrogen application regulation.

(Key Words: Management, Manure, Nitrogen, Phosphorus, Phytase.)

## Introduction

Pig numbers in the United States have not increased dramatically, but technological advances have greatly reduced the number of production operations. Although large confinement facilities have significantly increased production efficiency, they also have presented new management challenges in the collection, storage, and treatment of larger manure quantities. The quantities of manure and manure nutrients generated on a per acre basis have increased dramatically because of an increase in the number of hogs per operation that has not been matched by a proportional increase in the cropland acres associated with those operations. The European Union has recognized manure problems by imposing a tax on excreted phosphorus that corresponds to the number of animals.

Most regulations for livestock and poultry operations are targeted specifically to protect water resources from nonpoint source pollution. The nutrients of greatest concern from a water-quality perspective are nitrogen and phosphorus. Because nitrate contamination of drinking water is a potential health concern for people and animals that use groundwater for their water supply, most state guidelines and regulations for land application of manure are based on nitrogen requirements for crops.

Phosphorus generally does not pose a direct threat to human health, but excessive levels can degrade surface water quality by causing algal blooms. Such events increase the cost of water treatment for local municipalities. Because phosphorus is not subject to dissipation between excretion and land application, low nitrogen-to-phosphorus requirements in manure and high nitrogen-to-phosphorus requirements in plants make the land area required to distribute manure based on crop phosphorus needs two to four times as great as the land area required to distribute manure based on crop nitrogen needs. A Minnesota study found that less than 25% of producers surveyed had ever analyzed their manure for nutrient content, and that less than 20% had ever calibrated their manure spreaders. Thus, even where manure is applied, many producers still may apply their standard rate of inorganic fertilizer nutrients based on nitrogen and further increase soil phosphorus levels.

[1]Department of Agricultural Economics.

Corn and soybean meal, which are the primary ingredients in swine diets, contain phytic acid as the predominant form of phosphorus. Producers also add inorganic phosphorus to diets to meet the nutritional requirements. Phytic acid constitutes approximately 75% of total phosphorus in a typical swine diet. However, nonruminant animals like swine cannot utilize phytic acid, so it is excreted and contributes to the phosphorus problem.

Four methods have been proposed to reduce phosphorus application in excess of crop needs. One method is to apply manure over more acres at the phosphorus rate of uptake by the crop. The second method is to use synthetic amino acids as a replacement for soybean meal to reduce phosphorus intake of swine. Synthetic amino acids are expensive, and only lysine is used commonly. Phytase and low-phytic acid corn are two methods that increase availability of phytic acid phosphorus and reduce excretion and inorganic phosphorus intake. Phytase was approved for use in 1996, but low-phytic acid corn has not been released commercially. Thus, in the short run, the use of synthetic amino acids and phytase are the two alternatives available for producers who may be constrained by land.

The objective of this research was to determine benefits and costs of adopting phytase for a profit-maximizing feeder pig producer.

## Procedures

A optimization model was used that included information on: 1) feed nutrient and ingredient relationships, 2) feed nutrient conversion, 3) types of storage and application systems, 4) fertilizer nutrient conversion, and 5) regulations for storage and application. The crop grown by these producers was assumed to be continuous corn (which is used as a source of feed ingredients) and adjusted for a producer who disks or cultivates during the spring. Crop fertilizer requirements for this type of continuous corn are 140 lbs ($NH_4$) and 45 lbs ($P_2O_5$). Producer returns were assumed to be returns to management and operator labor. The number of market hogs on feed amounted to 2851 animals per market herd inventory with approximately three inventory turns per year.

The model maximizes the total value of an animal converted to the market herd inventory that moves through the system multiplied by the number of litters plus the fertilizer value of the manure (adjusted for losses), less the costs of feed, manure storage and application, and variable inputs. Constraints included additional manure storage capacity; minimum regulatory storage capacity; land application of manure nutrients according to their crop requirements; and the nutrient content of different ingredients (i.e., the standard least-cost feed ration constraints) The animal's live weight value included premiums and discounts, manure value, and costs, all functions of live weight.

## Results and Discussion

Figures 1 and 2 present the land requirements for nitrogen and phosphorus applications in the first year for different storage and application systems. As expected given the losses associated with each system, slurry tanks (lagoons) and injection (irrigation) yielded the highest (lowest) land requirements for either nitrogen or phosphorus application. Under a phosphorus-based scenario, this producer would require 2.02 (tank storage and injection application) to 5.03 (pit storage and irrigation application) times as much land than under a nitrogen-based scenario. This result suggests that a phosphorus-based application requirement on land has the potential to significantly affect pork producers who might be constrained by land.

Figures 3, 4, and 5 present the net returns (which were varied by the animal inventory number) for broadcast, injection, and irrigation applications. The results are reported by storage method (deep pits, slurry tanks, and lagoons) with land acreage held constant (100 acres). Several important results should be noted. First, in all cases, the total returns per animal are less than the results of our previous research, which did not include a

manure component, indicating that the cost of manure storage and application is greater than the value of the manure as a nutrient in crop production. Because the value of manure is negative after all economic costs and benefits are included, adopting a best management practices approach for manure may not be feasible without economic incentives.

A second result is that despite the cost of phytase being higher ($.195/lb of dicalcium phosphorus replaced) than the cost of dicalcium phosphorus ($.12/lb), a small proportion of phytase was an optimal ingredient when not enough land was available to utilize the nitrogen and phosphorus nutrients in crop production. The addition of phytase permitted more low-phytic acid phosphorus to be available in the corn for the animal, and corn is inexpensive relative to other ingredients containing phosphorus. This result suggests that the additional cost of manure storage is high enough so that producers who are constrained by land could consider using phytase, even though the unit cost is greater than that of the ingredients they are replacing. For producers who have excess land, phytase is not economically practical at these prices. Land requirements using phytase under a phosphorus-based application requirement declined by an average of approximately 30% from the numbers in Figure 2. This result further suggests that phytase is an alternative that producers might consider for reducing phosphorus excretion, if their state regulatory agency institutes a phosphorus-based application requirement and they are constrained by land.

Finally, when an additional inventory of animals was added and land acreage was held constant, net returns decreased dramatically because of the increased costs of constructing manure storage facilities. In this example, producers would rapidly suffer economic losses without expanding the amount of land because of the high cost of storage (returns would be less than $10 per year as shown in Figures 3 to 5). Additional storage is not a viable long-term strategy, so producers will be forced to find additional land for purchase or rent (average costs would decline more slowly), lease manure application rights from surrounding producers, hire custom manure disposal, or simply not increase the number of animals. This information can be used by policy makers to demonstrate to producers why simply increasing the size of a storage facility is not economically feasible when considering expansion without accounting for possible changes in land requirements.

Furthermore, policy makers should note that as the number of animals increased beyond the amount required for the market inventory, lagoon storage and irrigation application became the least-cost method to manage manure. However, this method maximizes nutrient losses to the environment rather than minimizing losses to ensure maximum use as fertilizer. Policy makers in the National Environmental Dialogue on Pork Production mediation process have strongly supported requiring producers to use storage methods that minimize environmental losses, such as tank storage or injection application.

Clearly, implementation of a phosphorus-based application requirement may impose hardships on producers who are constrained by land. Phytase is one alternative that can assist producers who might have difficulty meeting a phosphorus-based application requirement. Other technologies will also be likely available in the near future. Extension specialists and extension educators and financial lenders, who require a business plan with a manure management component, can use these results to show producers who are considering expansion that their projected returns must account for these potential policy considerations.

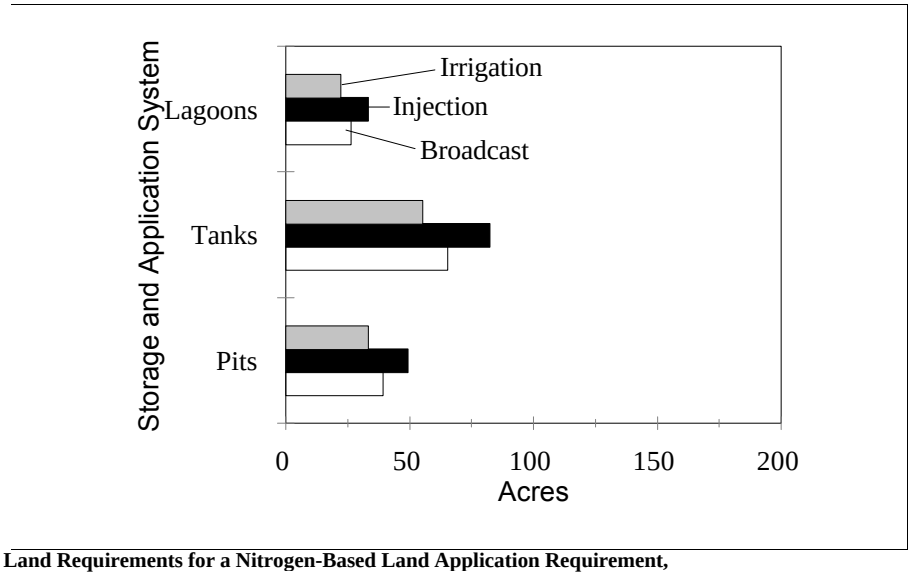



**Figure 1. Land Requirements for a Nitrogen-Based Land Application Requirement, by Storage and Application System.**

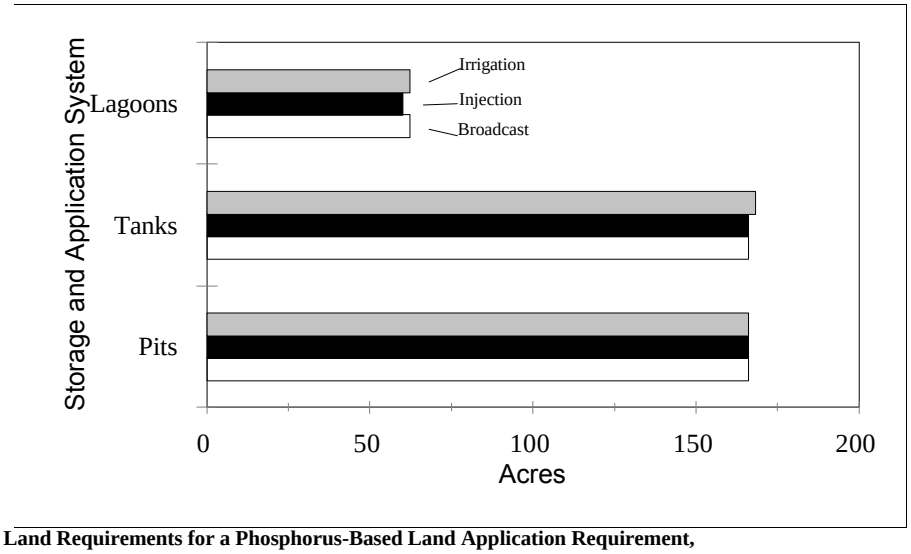



**Figure 2. Land Requirements for a Phosphorus-Based Land Application Requirement, by Storage and Application System.**

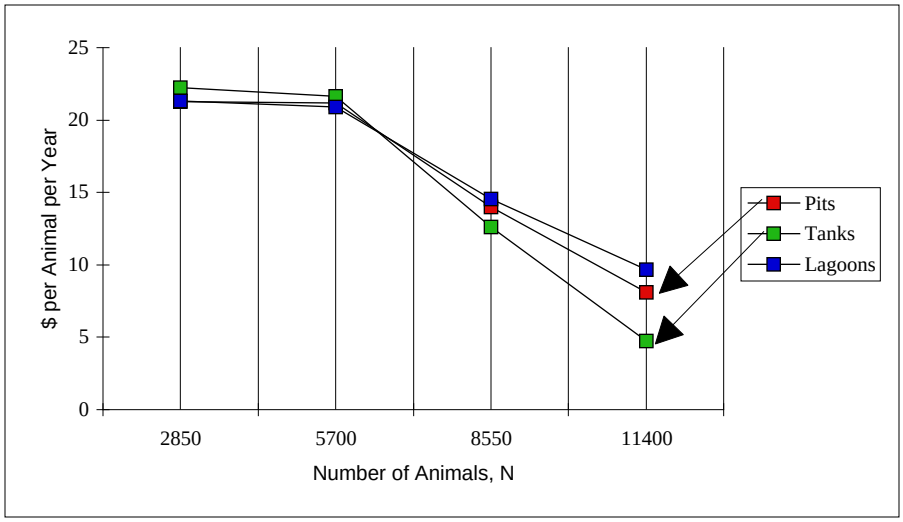



Figure 3. Returns per Animal per Year for Broadcast Application, by Market Herd Inventory and Storage System.

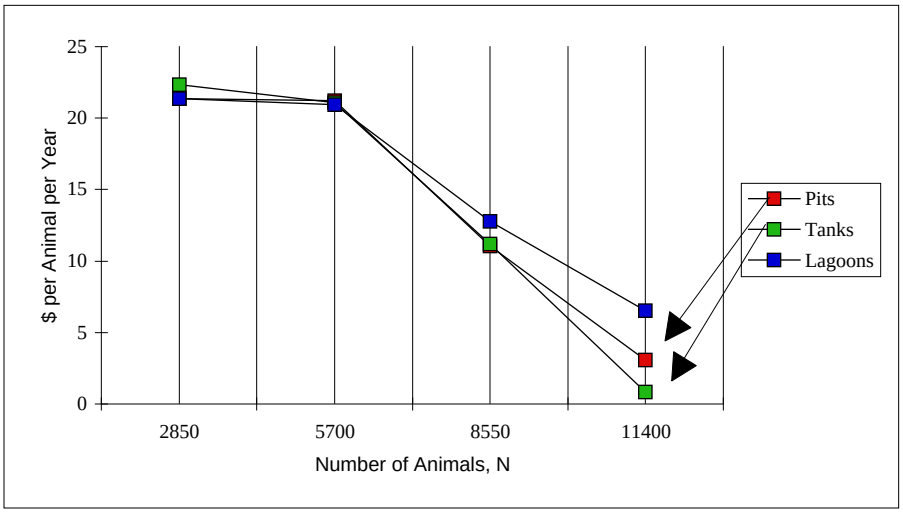



Figure 4. Returns per Animal per Year for Injection Application, by Market Herd Inventory and Storage System.

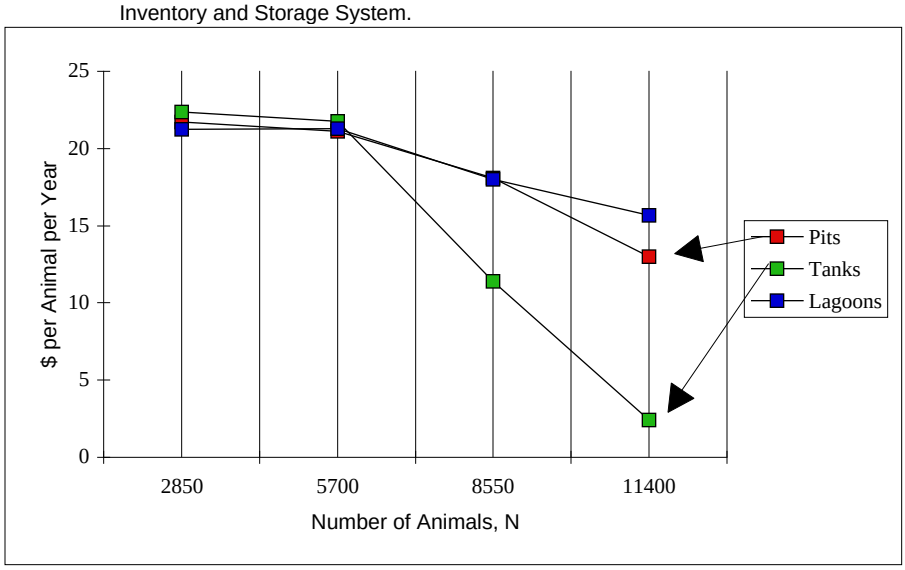



Figure 5. Returns per Animal per Year for Irrigation Application, by Market Herd Inventory and Storage System.

# COMPOSTING DEAD SWINE

*J. P. Murphy*[1] *and J. P. Harner*[1]

## Summary

Composting dead animals from a swine production facility offers an environmentally sound disposal method to many producers.

(Key Words: Composting, Dead Swine.)

## Introduction

Composting is a natural process whereby bacteria and fungi decompose organic material in a predominantly aerobic environment. Under controlled conditions, composting occurs in two stages. A high rate of biological activity results in rapid composting and high temperatures in the pile in the primary stage. This is when most of the organic breakdown occurs. The secondary stage has lower biological activity resulting in slower composting and lower pile temperatures. In this stage, the biological activity ends and the mixture stabilizes.

Proper conditions are required so that composting occurs rapidly, odor generation is minimized, and nuisance problems are presented. Conditions that can be controlled in the composting process are the material mix, moisture levels, porosity, and temperature.

## Material Mix

The proper compost mix requires a proper carbon to nitrogen (C/N) ratio to minimize odors generated yet offer an environment where microorganisms can flourish. Generally, a C/N ratio that is higher than 25:1 is satisfactory. Waste materials, such as manure, have a high N content resulting in a C/N ratio that is too low to compost. In order to compost these materials, amendments that contain a high C/N ratio or C content must be added. Plant materials such as wood chips, sawdust, or straw are ideal amendments for on-farm composting.

## Moisture Levels and Porosity

Proper moisture levels and a stable porous structure for the composting pile are two other conditions required to encourage bacterial growth and rapid composting. The moisture content of the mixture should be 50 to 60%.

The bacteria in a compost pile are aerobic or require oxygen. Open spaces or porosity must be maintained to provide oxygen and allow air to penetrate and move through the pile. Ideally, 35 to 50 % of the pile volume should be small open spaces to allow air movement through the pile.

## Temperature

The aerobic bacteria in the composting process grow at two temperature ranges: mesophilic (middle temperature) bacteria up to 100°F and thermophilic (high temperature) bacteria up to 150°F. The bacteria breaking down the materials in the pile generate heat and cause temperature increases. As the pile warms, different bacteria will grow at the higher temperatures. The mass of composting material will be more active and

[1]Department of Biological and Agricultural Engineering.

organic material will be broken down faster at higher temperatures. However, above 150°F, the rate of composting will decrease as bacteria are inactivated or even destroyed by the excessive temperatures.

Temperature increases warm air within the mixture. The air rises and moves out of the pile, while fresh air is drawn in. This process exhausts carbon dioxide ($CO_2$) created in the pile and maintains an aerobic environment for the bacteria. In addition, temperatures that remain above 130°F for 3 days will destroy disease-causing bacteria within the pile. Internal pile temperature is an indication of the current biological activity within the mixture and how well the pile is composting.

The composting process will generate heat and regulate its own temperature. However, to maintain high temperatures, the pile must have some insulation. A layer of inactive material (sawdust or finished compost) placed over the entire pile will insulate it. The insulation layer should be a foot or more in depth.

## Composter Location

The composter should be located away from sensitive water quality features such as streams, ponds, drainage ditches, and wells. The composter site should be well drained and provide all-weather capability for access roads and work areas.

Placement of a composter should consider the location of the farm residence and any nearby neighbor residences, and the view of passing vehicle traffic. Although offensive odors usually are not generated in the composting process, the handling of dead swine and the resulting compost on a daily basis is not aesthetically pleasing.

Consideration should be given to traffic patterns required in moving dead swine to the composter, storing and moving the required ingredients to the composter, and removing finished compost from the composter. A storage area for other composter ingredients (sawdust, straw, and crop residue) also needs to be considered. A water supply is necessary to regulate moisture in the compost pile.

## Composting Ingredients/Recipe

Composting dead swine requires the addition of a C source to ensure that a proper C/N ratio is present for the composting process. Sawdust is an ideal C source because of its small particle size, ease of handling, absorbency, and high C content. Sawdust seems to shed and/or absorb liquids sufficiently, so that leaching and drainage from the pile are minimal. Sawdust is preferred if big bales are used to form the compost structure. Composters utilizing straw or other crop residues may need to be placed in a roofed structure to keep rain from leaching through the pile. Crop residues can be chopped to reduce particle size and aid the composting process.

Experience with sawdust as a C ingredient indicates that about one-third to one-half cubic yd of sawdust per sow in the herd is required annually to support the composting process in a farrow-to-finish operation. Hence, a producer with a 100-sow herd would need in the range of 35 to 50 cubic yd of sawdust per year to operate the composter. Sawdust is used in swine composters at the approximate ratio of 100 cubic ft of sawdust per 1000 lbs of dead swine. Hence, a producer anticipating 10,000 lbs of death loss per year could expect to use about 1000 cubic ft, or 37 cubic yd of sawdust per year.

## Composter Design

The composting process requires that the proper ingredients be placed in composting "bins" in the correct proportions (Figure 1) for an adequate composting period prior to moving the material to a second bin for the secondary stage. Composting bins or structures typically are designed for a 3 mo storage and composting interval.

Field experience suggests that outside composting bins can be constructed using large round bales (5 ft - 6 ft in diameter) of

low-quality hay. Bales are placed end-to-end to form walls for 3-sided enclosures (bins). A minimum of 2 bins is required for primary and secondary composting phases. However, more bins may be required on larger operations or with different management schemes. Excessively large bins should be avoided. Experience suggests that 1.25 to 1.50 sq ft of bin area per sow in the sow herd is necessary for composting. Hence, a 100-sow herd would require 125 to 150 sq ft of area in the primary and secondary composting bins. A layout of 2 bales deep and 3 bales wide provides this approximate area and has worked well. Bin area requirements also can be determined on the basis of 10 to 12 sq ft of bin area per 1000 lbs of carcass composted annually. An operation anticipating 10,000 lbs of death loss annually would need a composter with 100 to 120 sq ft in each of the primary and secondary bins. Consideration might be given to providing an additional bin or bins for storage of sawdust or crop residues.

Bin configuration is not critical; however, bins should be laid out so that the contents are easily accessible with a front-end or skid-steer loader. Square bins offer the greatest opportunity for reduced side effects (e.g., heat loss through walls). However, long, narrow bins, that can be accessed through both ends also have been used. Primary and secondary bins should be located adjacent to each other to facilitate moving the compost.

## Composter Operation and Maintenance

Composter bins can be made inside a structure or outside in a pile or round bale containment (Figure 2). Some guidelines for composting are discussed below.

Step1. Start a primary composting bin by placing enough sawdust in the bin to provide a base of 1 to 2 ft.

Step 2. Place carcasses in the primary bin as necessary. Use sufficient sawdust such that each carcass is covered on all sides with a minimum of 1 ft of sawdust. Expect to use sawdust at the rate of 100 cubic ft of sawdust per 1000 lbs of dead swine. Additional sawdust may be needed after 1 or 2 days to re-cover the carcass, because settling will occur.

Step 3. Continue placing and covering carcasses as necessary, until the bin is full. Experience suggests that the last carcasses placed in the primary bin should be allowed to compost for a minimum of 3 months. Longer composting periods provide greater breakdown, especially in periods of cold weather.

Step 4. After the last carcasses placed in the primary bin have composted for at least 3 months, move the contents of the primary bin to a secondary bin for the second stage of composting. A thorough mixing of contents should occur during the transfer process.

Step 5. Allow the secondary bin to compost for another 3 months or longer. After this secondary stage of composting is completed, the compost should appear as a dark, nearly black, humus-like material with very little odor. Some large, resistant carcass parts (teeth or skulls) may still be identifiable but should be soft and easily crumbled.

Step 6. After secondary composting is completed, the compost can be hauled and spread on the land with conventional manure-spreading equipment.

Step 7. Keep fresh sawdust as dry as possible, because dry sawdust works much better in the composting. Fresh sawdust in a pile will shed water reasonably well if the pile is “mounded”, with no pockets or depressions.

Step 8. Keep the area around the composter mowed and free of tall weeds and brush. Watch for any leachate from the composter and take steps to eliminate any leaching that might occur. Using more sawdust in the bottom of the bins can help eliminate leaching.

**Biosecurity** Control of pathogens and disease transmission is critical to most swine operations.

Traffic patterns to and from the composting area need to be assessed for biosecurity implications. The composting process will destroy most diseases with high temperatures. Bacteria and viruses from fresh carcasses can be passed through the transport vehicle to production housing. Farm employees should be trained in the biosecurity implications of operation and traffic control of the composter. Scavenging animals and vermin also must be kept from the compost pile. Maintaining the recommended cover over the compost pile should reduce the problem. Fencing may have to be installed if scavenging animals cause problems.

## Acknowledgment

The information in this report was taken from a series of publications developed by Ohio State University and the University of Missouri. Much of the work on swine composting has been done by these universities. The, figures below are from Ohio State University, Extension Fact Sheets AEX 711-97 (Fig. 1) and AEX 712-97 (Fig. 2).

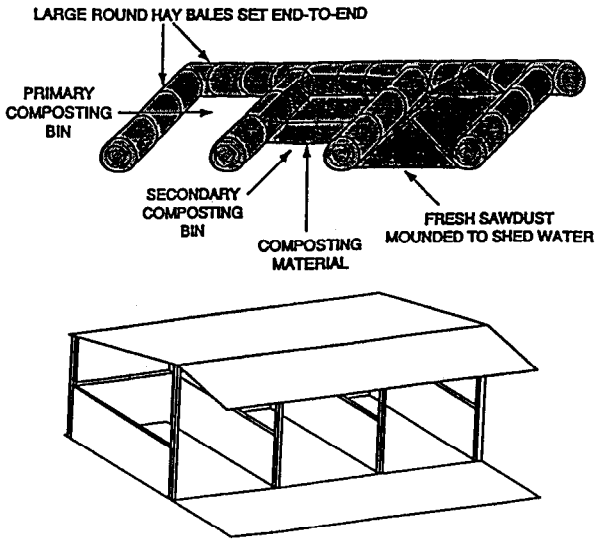



**Figure 1. Construction of a Composting Pile for Dead Swine.**

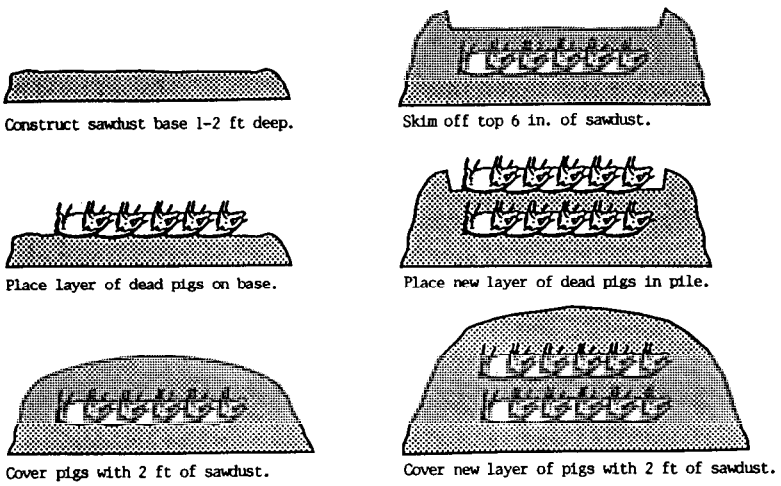



**Figure 2. Bin System for Composting Dead Swine.**

# EFFECTS OF BRANCHED CHAIN AMINO ACIDS ON SOW AND LITTER PERFORMANCE [1]

***S. A. Moser, M. D. Tokach [2], J. L. Nelssen, R. D. Goodband, and J. A. Loughmiller***

## Summary

Three hundred-six sows were used to evaluate effects of the interrelationship among valine, isoleucine, and leucine on sow and litter performance. Eight dietary treatments were arranged as a 2×2×2 factorial with two levels of valine (.80 and 1.20%), isoleucine (.68 and 1.08%), and leucine (1.57 and 1.97%). Litter weaning weight, litter weight gain from d 2 to weaning, and sow backfat loss increased as dietary valine increased but were not affected by dietary isoleucine or leucine. Increasing dietary valine, isoleucine, or leucine did not affect milk fat, DM, CP, or lactose. These results confirm the importance of dietary valine for increased litter weaning weight, independent of either additional dietary isoleucine or leucine.

(Key Words: Valine, Isoleucine, Leucine.)

## Introduction

Research conducted prior to 1990 evaluating the valine, isoleucine, and leucine requirements of lactating sows utilized litters with nine or fewer pigs weaned and preweaning growth rates that were 50% of current production rates. Increased genetic selection and improvements in management have dramatically increased the production capability of the modern commercial sow. These high producing sows require considerably higher levels of total dietary valine because of increased milk production. More recently, research conducted at Kansas State University has found that increasing total dietary valine from .75 to 1.15% in lactation diets resulted in increased litter weight gain. Recent research has found that increasing both dietary valine and isoleucine in lactation diets increased litter weaning weights. Therefore, the objective of this experiment was to determine if the improved litter weaning weights observed with the increased dietary valine was specific for valine or if other branch chain amino acids (isoleucine or leucine) also will improve litter weaning weights.

## Procedures

Three hundred-six primiparous and multiparous sows (36 to 41 per treatment) from the Kansas State University Swine Teaching and Research Center were used in this experiment. All sows were maternal line (PIC Line C-22) and were bred to terminal line (PIC Line 326 ) boars. During gestation, sows were housed in outside dirt lots and fed in individual stalls. Gestating sows were fed 4 to 5 lb/d depending on body condition. The gestation diet was a sorghum-soybean meal-based diet formulated to .65% total lysine, .90% Ca, and .80% P. On d 109 of gestation, sows were moved into farrowing crates in an environmentally regulated farrowing house. All sows were fed the gestation diet until farrowing, at which time sows were allotted to one

[1]Appreciation is expressed to Lonza, Inc., Fair Lawn NJ, for partial financial assistance in this trial. We also express appreciation to the Kansas DHIA for their assistance with chemical analysis of milk samples.

[2]Northeast Area Extension Office, Manhattan, KS.

of eight dietary treatments. Treatments were allotted randomly within groups of eight as sows farrowed to minimize variation in lactation length between treatments. Litter size was equalized by 24 h after farrowing, and all sows began the study with at least 10 pigs. Sows were allowed ad libitum access to feed and water from parturition until weaning. Orts were collected and weighed on d 7 and 14 and at weaning to determine the sow's average daily feed intake. Creep feed was not offered to litters. Backfat was measured using real-time ultrasound 6 cm off the midline on both sides of the body at the last rib. Pigs and sows were weighed on d 0, 7 and 14 and at weaning. Sows farrowed from November 1996 through December 1997. Three or four observations were made per treatment for each lactation group, and 12 lactation groups (blocks) were used.

The lactation diets (Table 1) were formulated to meet or exceed amino acid requirement estimates based on ratios relative to lysine, except for valine, isoleucine, and leucine. All other nutrients were in excess of published requirement estimates. Diets were formulated to .90% total lysine, .90% Ca, and .80% P. The control diet was formulated to contain .80% valine, .68% isoleucine and 1.57% leucine. Cornstarch was replaced in .40% increments with L-valine, L-isoleucine, L-leucine, or a combination of each to provide the remaining seven experimental diets. The treatments included two levels of valine (.80 and 1.20%), isoleucine (.68 and 1.08%), and leucine (1.57 and 1.97%).

Sixteen sows per treatment were milked manually on d 14 to 16 of lactation. All sows were milked approximately 2 h after the noon feeding. Sows were separated from their litters for a minimum of 30 min before milking. Milk letdown was enhanced by infusing 10 IU of oxytocin into an ear vein of the sow. Sows were restrained, and 75 mL of milk was collected from the first two productive glands on both sides of the body. Samples from each gland were pooled for chemical analysis and stored at 35 to 40°F. All analyses were conducted within 48 h after collection.

**Table 1. Diet Composition (As-Fed Basis)[a]**

| Ingredients | % |
|---|---|
| Corn | 71.08 |
| Soybean meal (46.5% CP) | 20.06 |
| Choice white grease | 3.00 |
| Monocalcium phosphate (21% P) | 2.25 |
| Limestone | 1.08 |
| Cornstarch[b] | 1.20 |
| Salt | .50 |
| Sow add pack | .25 |
| Vitamin premix | .25 |
| Trace mineral premix | .15 |
| L-Lysine-HCl | .15 |
| L-Threonine | .016 |
| L-Tryptophan | .016 |

[a]Basal diet was formulated to 15.5% CP, .90% lysine, .80% valine, .68% isoleucine, 1.57% leucine, .90% Ca, and .80% P.
[b]Cornstarch was replaced in .40% increments with L-valine, L-isoleucine, L-leucine, or a combination of each to provide remaining seven experimental diets.

Lactation group was used to block all response criteria. Litter size after cross-fostering was used as a covariate for litter weights, litter weight gain, and ADFI. Lactation length was used as a covariate for litter weaning weight, litter weight gain from d 2 to weaning, sow weight change and backfat change from d 0 to weaning, and ADFI. Initial sow weight and beginning backfat measurement also were used as covariates for sow weight change and backfat change, respectively. Parity was a significant covariate for milk fat, lactose, and DM but not for CP or ash. Contrasts were the following: main effects of valine, isoleucine, and leucine and all two-way and three-way interactions.

## Results

No valine × isoleucine × leucine interactions affected the number of pigs after fostering, number of pigs weaned, or lactation length (P>.15; Table 2). Also no three-way

interactions among the amino acids affected any of the litter weights or litter weight gain measurements (P>.15). Valine × isoleucine × leucine interactions tended to affect total branched chain amino acid intake (P<.08) and sow backfat change (P<.13). There was a tendency for valine × isoleucine interactions affecting litter weight on d 7 (P<.11) and d 14 (P<.12). These interactions appeared to be results of increased litter weight with increasing isoleucine in sows fed .80% valine, whereas increasing isoleucine decreased litter weights in sows fed 1.20% valine.

**Valine.** Dietary valine had no effect on number of pigs weaned ($\bar{x}$ = 10.6; Table 2) or survival rate after cross-fostering ($\bar{x}$ = 94.5%). Comparing the overall effects shows that increasing dietary valine from 47.52 to 63.87 g/d (.80 to 1.20%), regardless of isoleucine or leucine, increased (P<.06) litter weights throughout each week as well as the overall 21 d lactation period (Table 2). Valine and TBCAA intakes increased (P<.0001) whereas leucine and lysine intake decreased (P<.01) as dietary valine increased (Table 3). Sow ADFI (P>.50) and sow weight loss (P>.30) were not affected. As dietary valine increased from .80 to 1.20%, sow backfat loss increased (P<.02).

**Isoleucine.** Dietary isoleucine had no effect (P>.10) on number of pigs weaned, pig survival rate, litter weights, litter weight gains, (Table 2), sow weight change, and sow backfat change (Table 3). Dietary isoleucine had no effect on sow feed intake (P>.42; Table 3), but isoleucine and TBCAA intakes increased (P<.0001) as isoleucine increased. Valine intake decreased (P<.002) with increased dietary isoleucine.

**Leucine.** Dietary leucine had no effect on number of pigs weaned, pig survival rate, litter weights, or litter weight gain (Table 2). Sow backfat loss (P>.29) was not affected by increased dietary leucine; however, sow BW loss (P<.15) had a tendency to decrease (Table 3). Daily leucine and TBCAA intakes (P<.0001) increased as dietary leucine increased and daily lysine intake decreased (P<.0004). Leucine had no effect on sow ADFI (P>.58).

**Milk Composition.** Increasing dietary valine, isoleucine, and leucine did not affect milk DM, CP, fat, or lactose (Table 4). The addition of dietary isoleucine caused milk ash to decrease (P<.05), but increasing valine and leucine had no effect.

## Discussion

Increasing dietary valine from .80% to 1.20% increased litter weaning weight by 4.4 lb and litter weight gain from d 2 to weaning by 3.7 lb, independent of dietary isoleucine and leucine. This suggests that increasing dietary valine increases milk production as measured by litter weaning weights regardless of dietary isoleucine or leucine.

This response to valine has been observed in previous experiments conducted with high-producing sows at Kansas State University. In an experiment reported in the 1994 KSU Swine Day Report of Progress, as the valine level was increased from .75 to 1.15%, litter weaning weights linearly increased by 8.2 lb and litter weight gain increased by 7.5 lb. In our experiment, no change in sow weight or ADFI was observed when additional valine was added. However, an increase occurred in last rib backfat loss, but it was minimal (.06 in). Previous research elicited the same lack of response for sow weight change and ADFI, but last rib backfat also did not change.

Previous research has reported that increasing isoleucine from .50 to 1.20% increased litter weaning weight, with the greatest response achieved when isoleucine was increased from .50 to .85%. The isoleucine level of .85% in that experiment is intermediate to our levels of .68 and 1.08%. Our data do not necessarily refute the previous data, because we observed a numerical increase in litter weaning weight and litter weight gain when sows were fed the low level of valine (.80%) and the high level of isoleucine (1.08%).

Our study showed no response to the addition of leucine. Diets formulated to meet conventional lysine requirements don't appear to be deficient in leucine.

Research using mammary vein cannulation in sows and dairy cows has shown that isoleucine and valine are taken up by the mammary gland in amounts 30 to 80% greater than their output in milk protein. The branched chain amino acids seem to serve a purpose other than milk protein synthesis. Valine and isoleucine likely are used as energy sources in the mammary gland. Milk composition was not altered when valine was added to the diet, so we can conclude that the increase in litter weaning weight could be attributed to increased milk yield, although milk yield was not measured directly in this experiment. Leucine had no effect on any of the milk criteria in our experiment.

The valine requirement of high-producing lactating sows appears to be greater than current estimates by the National Research Council and Agricultural Research Council. The increases in litter weights and litter weight gain with increased valine, independent of isoleucine and leucine, indicate that the response is due entirely to valine and not to the total branched chain amino acid level of the diet. In conclusion, leucine and isoleucine did not elicit the same magnitude of response; thus, the importance of valine for milk production must be considered when formulating lactation diets.


**Swine Nutrition Graduate Students: Front row (L to R), Manual De La Llatta, Ann Amornthewaphat, Hong Cao, Patrick O'Quinn and Dustin Dean. Back row (L to R), Matt Steidinger, Jason Woodworth, Joe Loughmiller, Craig Maloney, David Lee, Grant Grinstead, Rob Musser, Joel DeRouchey, and Jin-Seong Park. Not pictured, Sharlie Moser.**

**Table 2. Effects of Increasing Isoleucine, Leucine, and(or) Valine on Litter Growth Performance[a]**

| Valine, % | .80 | | | | 1.20 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Isoleucine, % | .68 | | 1.08 | | .68 | | 1.08 | | |
| Leucine, % | 1.57 | 1.97 | 1.57 | 1.97 | 1.57 | 1.97 | 1.57 | 1.97 | |
| Item TBCAA, %[b] | 3.05 | 3.45 | 3.45 | 3.85 | 3.45 | 3.85 | 3.85 | 4.25 | SE |
| No. of sows | 40 | 38 | 39 | 38 | 38 | 36 | 36 | 41 | - |
| Mean parity | 2.0 | 2.2 | 2.1 | 2.1 | 2.0 | 2.3 | 2.2 | 2.1 | .14 |
| No. of pigs after fostering | 11.1 | 11.2 | 11.3 | 11.1 | 11.3 | 11.2 | 11.1 | 11.0 | .16 |
| No. of pigs weaned | 10.6 | 10.5 | 10.5 | 10.6 | 10.6 | 10.5 | 10.6 | 10.6 | .13 |
| Lactation length, d | 20.5 | 20.9 | 20.7 | 20.8 | 21.0 | 20.8 | 20.8 | 20.6 | .24 |
| Litter wt, lb | | | | | | | | | |
| Day 2 | 42.8 | 42.3 | 44.1 | 43.7 | 43.7 | 45.0 | 43.0 | 44.3 | .95 |
| Day 7[d] | 65.8 | 64.5 | 66.9 | 66.5 | 68.5 | 69.0 | 66.1 | 67.9 | 1.46 |
| Day 14[d] | 103.1 | 102.2 | 105.7 | 103.8 | 108.2 | 108.1 | 103.5 | 107.2 | 2.22 |
| Weaning[cd] | 135.9 | 135.6 | 138.8 | 139.2 | 143.4 | 142.5 | 138.3 | 143.0 | 2.88 |
| Litter wt gain, lb | | | | | | | | | |
| Day 2 to 7[d] | 22.9 | 22.0 | 22.9 | 22.9 | 24.9 | 24.0 | 23.1 | 23.6 | .88 |
| Day 2 to 14[d] | 60.2 | 59.7 | 61.5 | 60.2 | 64.6 | 63.1 | 60.6 | 63.1 | 1.79 |
| Day 2 to weaning[cd] | 93.3 | 93.3 | 94.9 | 95.6 | 99.7 | 97.6 | 95.3 | 98.9 | 2.48 |

| | Statistical Analysis ( P <) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Interactions | | | | Main Effects | | |
| Item | Val×Ile× Leu | Ile × Leu | Val × Leu | Val × Ile | Leu | Ile | Val |
| Mean parity | .89 | .18 | .73 | .79 | .30 | .99 | .50 |
| No. of pigs after fostering | .78 | .43 | .60 | .32 | .57 | .45 | .84 |
| No. of pigs weaned | .94 | .46 | .92 | .85 | .60 | .97 | .70 |
| Lactation length, d | .69 | .65 | .19 | .48 | .81 | .95 | .55 |
| Litter weights | | | | | | | |
| Day 2 | .96 | .99 | .18 | .15 | .51 | .67 | .29 |
| Day 7 | .92 | .58 | .33 | .11 | .88 | .94 | .06 |
| Day 14 | .44 | .65 | .31 | .12 | .91 | .83 | .05 |
| Weaning | .54 | .44 | .63 | .17 | .62 | .81 | .03 |
| Litter weight gain, kg | | | | | | | |
| Day 2 to 7 | .82 | .36 | .88 | .27 | .64 | .55 | .05 |
| Day 2 to 14 | .32 | .57 | .59 | .25 | .83 | .61 | .06 |
| Day 2 to weaning | .47 | .36 | .91 | .32 | .76 | .91 | .04 |

[a]Litter size after cross-fostering was used as a covariate.

[b]Total branched-chain amino acids (isoleucine + valine + leucine).

[c]Lactation length was used as a covariate.

[d]Parity was used as a covariate.

**Table 3. Effects of Increasing Isoleucine, Leucine, and(or) Valine on Sow Feed Intake, Body Weight, and Backfat Changes[a]**

| Valine, % | .80 | | | | 1.20 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Isoleucine, % | .68 | | 1.08 | | .68 | | 1.08 | | |
| Leucine, % | 1.57 | 1.97 | 1.57 | 1.97 | 1.57 | 1.97 | 1.57 | 1.97 | |
| Item TBCAA, %[b] | 3.05 | 3.45 | 3.45 | 3.85 | 3.45 | 3.85 | 3.85 | 4.25 | SE |
| Daily intake | | | | | | | | | |
| ADFI, lb[c] | 13.1 | 12.7 | 13.0 | 12.9 | 13.1 | 12.9 | 12.6 | 12.9 | .20 |
| Lysine, g[c] | 55.3 | 52.2 | 53.6 | 52.2 | 52.2 | 50.9 | 53.3 | 51.0 | .80 |
| Valine, g[c] | 47.8 | 48.6 | 46.1 | 47.5 | 64.0 | 66.1 | 63.1 | 62.0 | .90 |
| Isoleucine, g[c] | 40.7 | 40.5 | 57.8 | 60.5 | 38.6 | 40.4 | 60.4 | 58.1 | .85 |
| Leucine, g[c] | 88.8 | 102.2 | 88.4 | 105.1 | 83.7 | 102.5 | 85.4 | 102.6 | 1.48 |
| TBCAA, g[c] | 177.4 | 191.3 | 192.3 | 213.1 | 186.4 | 209.1 | 208.9 | 222.8 | 3.12 |
| Sow BW, lb | | | | | | | | | |
| Day 0 | 438.3 | 457.9 | 451.3 | 442.2 | 448.9 | 451.3 | 450.4 | 450.6 | 8.91 |
| Change[d] | -9.48 | -7.58 | -9.37 | -4.87 | -11.99 | -8.44 | -11.60 | -8.09 | 3.33 |
| Sow backfat, mm | | | | | | | | | |
| Day 0 | .62 | .57 | .60 | .56 | .57 | .60 | .60 | .63 | .03 |
| Change[e] | -.04 | -.03 | -.03 | -.04 | -.06 | -.06 | -.08 | -.04 | .02 |

Statistical Analysis (P <)

| | Interactions | | | | Main Effects | | |
|---|---|---|---|---|---|---|---|
| Item | Val × Ile × Leu | Ile × Leu | Val × Leu | Val × Ile | Leu | Ile | Val |
| Daily intake | | | | | | | |
| ADFI | .73 | .24 | .42 | .35 | .58 | .42 | .59 |
| Lysine | .23 | .81 | .69 | .23 | .0004 | .85 | .01 |
| Valine | .14 | .32 | .62 | .39 | .21 | .002 | .0001 |
| Isoleucine | .003 | .64 | .24 | .33 | .39 | .0001 | .40 |
| Leucine | .25 | .69 | .16 | .85 | .0001 | .32 | .01 |
| TBCAA | .08 | .82 | .84 | .94 | .0001 | .0001 | .0001 |
| Sow BW | | | | | | | |
| Day 0 | .29 | .23 | .76 | .88 | .60 | .94 | .65 |
| Change | .78 | .79 | .94 | .82 | .15 | .70 | .35 |
| Sow backfat | | | | | | | |
| Day 0 | .94 | .86 | .05 | .32 | .67 | .56 | .54 |
| Change | .13 | .91 | .32 | .95 | .29 | .97 | .02 |

[a]Lactation length and parity were used as covariates.
[b]Total branched-chain amino acids (isoleucine + valine + leucine).
[c]Pigs equalized after cross fostering was used as a covariate.
[d]Initial BW was used as a covariate.
[e]Beginning backfat measurement was used as a covariate.

**Table 4. Effects of Valine, Isoleucine, and Leucine on Milk Composition [a]**

| | Valine, % | .80 | | | | 1.20 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Isoleucine, % | .68 | | 1.08 | | .68 | | 1.08 | | |
| | Leucine, % | 1.57 | 1.97 | 1.57 | 1.97 | 1.57 | 1.97 | 1.57 | 1.97 | |
| Item | TBCAA, %[b] | 3.05 | 3.45 | 3.45 | 3.85 | 3.45 | 3.85 | 3.85 | 4.25 | SE |
| Milk urea nitrogen, mg/dl[c] | | 49.23 | 47.65 | 48.74 | 50.11 | 52.26 | 51.61 | 50.44 | 50.76 | 1.84 |
| DM, %[c] | | 16.76 | 17.06 | 16.91 | 16.67 | 16.63 | 16.84 | 16.76 | 16.97 | .23 |
| CP, % | | 4.60 | 4.58 | 4.49 | 4.55 | 4.55 | 4.47 | 4.47 | 4.51 | .08 |
| Fat, %[c] | | 5.12 | 5.40 | 5.31 | 5.21 | 4.95 | 5.23 | 5.37 | 5.43 | .18 |
| Lactose, %[c] | | 5.82 | 5.75 | 5.87 | 5.87 | 5.89 | 5.89 | 5.83 | 5.87 | .06 |
| Ash, % | | 4.50 | 4.07 | 4.11 | 4.14 | 4.27 | 4.31 | 4.06 | 4.18 | .12 |

Statistical Analysis ( P < )

| | Interactions | | | | Main Effects | | |
|---|---|---|---|---|---|---|---|
| | Val × Ile × Leu | Ile × Leu | Val × Leu | Val × Ile | Leu | Ile | Val |
| Milk urea nitrogen | .70 | .44 | .98 | .37 | .92 | .89 | .07 |
| DM | .39 | .42 | .58 | .44 | .46 | .96 | .76 |
| CP | .86 | .37 | .72 | .63 | .98 | .39 | .35 |
| Fat | .75 | .23 | .75 | .22 | .30 | .22 | .91 |
| Lactose | .89 | .51 | .46 | .13 | .79 | .54 | .31 |
| Ash | .27 | .10 | .09 | .96 | .47 | .05 | .97 |

[a]Values represent the means of 16 sows/treatment.

[b]Total branched-chain amino acids (isoleucine + valine + leucine).

[c]Parity was used as a covariate.


**Terry Gugle, ASI Feedmill Manager.**

# EFFECTS OF INCREASED DIETARY LYSINE ON SOW AND LITTER PERFORMANCE [1]

***R. E. Musser, R.D. Goodband J. L. Nelssen, M. D. Tokach [2], and S. S. Dritz [3]***

## Summary

Three hundred and fifty three lactating sows were used to determine the effects of increased dietary lysine on sow and litter performance. At farrowing, sows were assigned to corn-soybean meal lactation diets consisting of either 1.0 or 1.3% total lysine. A treatment by parity interaction was observed, with first parity sows fed 1.3% lysine having heavier litter weaning weights than sows fed 1.0% lysine. Surprisingly, third and fourth parity sows fed 1.3% lysine had lower litter weaning weights than those fed 1.0% lysine. No other treatment by parity interactions existed. No differences were observed in the number of pigs weaned or pig survivability. Sow fed 1.3 % lysine tended to consume less feed in the first week of lactation than sow fed 1.0% lysine (9.6 vs 10.0 lb/d), with no differences observed during week 2 or overall. No differences were observed in subsequent performance of the sows on days to estrus; farrowing rate; or number of pigs born, born alive, stillborn, or born mummified. This experiment showed that increasing dietary lysine from 1.0% to 1.3% increased litter weaning weights for parity 1 sows but not for older sows.

(Key Words: Lysine, Lactation, Weaning Weight, Sows.)

## Introduction

In recent years, a substantial amount of genetic improvement has occurred in lactating sow performance. With the genetic improvement, concern about the lysine requirement for the lactating sow has risen. A recent review from Biokyowa, Brain Kerr of past lactation experiments has established that the major component driving the sow's lysine requirement is litter weight gain (0.0214 × litter weight gain g/d + .864)= lysine requirement). Although this equation helps to establish the requirement for lactating sow performance, the effects on subsequent farrowing performance are not considered. This experiment investigated the effects of increasing dietary lysine on sow and litter performance as well as for subsequent farrowing rate and total pigs born.

## Procedures

A total of 353 sows (PIC C15 × 326) was used from July to September of 1996 on a 1,400 sow commercial farm in North Central Kansas. Sows were allotted to one of two dietary treatments at d 110 of gestation when placed in the farrowing facility. At farrowing, the number of pigs born alive, stillborn, and mummified were recorded. All litters were equalized within 48 h after farrowing to approximately 10.5 pigs. Litter weight was

[1]The authors would like to thank Keesecker Agri-Business for use of facilities and animal care.

[2]Northeast Area Extension Office, Manhattan, KS.

[3]Food Animal Health and Management Center.

recorded at weaning to determine the effect of increased lysine concentration on litter growth rate. Sows were provided ad libitum access to feed and water, and feed intake was recorded daily. At weaning, sows were moved to the breeding facility and monitored for estrus with daily boar exposure. Sows that were rebreed were monitored to determine the effect on the subsequent farrowing rate, number of pigs born, born alive, stillborn, and born mummified. In the statistical analysis, sows were combined into four parity groups; parity 1, parity 2, and parity 3 and 4 sows, and all sows greater than parity 4.

## Results

Increasing the dietary lysine from 1.0% to 1.3% resulted in a treatment by parity interaction. Parity 1 sows fed 1.3% lysine weaned heavier litters than sows fed 1.0% lysine (Table 2). However, parity 3 and 4 sows fed the 1.3% lysine diet produced litters that were lighter at weaning than those of sows fed 1.0% lysine, which was unexpected. Lysine by parity interactions were not observed for any other litter criteria (P>.05). No differences were observed in the number of pigs born, born alive, stillborn, or born mummified (P>.05; Table 3). No differences were observed in number of pigs equalized within 48 h of farrowing, number of pigs weaned, or pig survivability (P>.05).

Sow daily feed intake (Table 3) was decreased by increasing dietary lysine from 1.0 to 1.3% during the first week of lactation (P = .02), with no difference observed in week 2 or overall feed intake.

In the analysis of the subsequent reproductive performance, we observed no differences in days to return to estrus; farrowing rate; or the number of pigs born, born alive, stillborn, or born mummified per litter (P>.05; Table 4).

## Discussion

Using the equation from Biokyowa that was discussed in the introduction, we determined that all sows in this experiment had lysine intakes above the estimated requirement with the weaning weights that were observed (Figure 1). However, increasing dietary lysine from 1.0% to 1.3% in the lactation for parity 1 sows increased litter weaning weights. We speculate that this may be because the parity 1 sow is still growing and may require more lysine to establish milk production and also meet the need to increase body reserves. Therefore, this experiment suggests that using a 1.0% lysine level in the lactation diet will have no negative effect on subsequent litter performance, but a higher level of dietary lysine may improve litter weaning weights. In the analysis of the subsequent farrowing data ,we observed no differences with increased dietary lysine, showing that 1.0% (approximately 45 grams/d) is a sufficient level for maximizing subsequent farrowing performance for sows used in this experiment. However, the total grams of lysine intake instead of percent lysine should be considered when calculating the requirement for your herd.

**Table 1. Experimental Lactation Diets[a]**

| | Dietary Lysine, % | |
|---|---|---|
| Ingredient, % | 1.0 | 1.3 |
| Corn | 68.10 | 57.01 |
| Soybean meal 46.5% | 27.57 | 38.84 |
| Monocalcium phosphate | 2.05 | 1.84 |
| Limestone | 1.13 | 1.16 |
| Salt | .50 | .50 |
| Sow vitamin premix | .25 | .25 |
| Vitamin premix | .25 | .25 |
| Trace mineral premix | .15 | .15 |

[a]Diets formulated to contain .90 Ca, .80 P., and approximately 1500 Mcal ME.

**Table 2. Effects of Dietary Lysine by Parity Interactions on Litter Weaning Weights (lb)**[a]

| | Dietary Lysine, % | | | |
|---|---|---|---|---|
| Item, | 1.0 | 1.3 | SEM | Parity effect (P <) |
| Parity 1 | 98.8 | 106.7 | 3.16 | .03 |
| Parity 2 | 107.8 | 111.4 | 3.16 | .38 |
| Parity 3 and 4 | 115.3 | 107.2 | 3.16 | .06 |
| Parity 5 and above | 117.0 | 116.4 | 3.16 | .90 |

[a]Lactation length was used as a covariate.

**Table 3. Effects of Dietary Lysine on Sow Performance**

| | Dietary Lysine, % | | | |
|---|---|---|---|---|
| Item, | 1.0 | 1.3 | SEM | P < |
| No. of sows | 181 | 172 | | |
| Parity | 2.97 | 2.72 | .14 | .22 |
| Lactation length, d | 16.7 | 17.0 | .09 | .01 |
| Total number of pigs born | 11.2 | 11.7 | .21 | .10 |
| Number pigs born alive | 10.4 | 10.8 | .21 | .15 |
| Number stillborn | .55 | .73 | .07 | .08 |
| Number mummified | .26 | .19 | .04 | .28 |
| Number pigs day 2 | 10.5 | 10.4 | .06 | .75 |
| Pigs weaned [a] | 9.7 | 9.8 | .07 | .61 |
| Pig survival,% [a] | 93.2 | 93.5 | .63 | .77 |
| Average daily feed intake, lb/d | | | | |
| Week 1 | 9.6 | 10.0 | .14 | .02 |
| Week 2 | 11.8 | 11.8 | .17 | .99 |
| Overall | 10.7 | 10.9 | .13 | .31 |

[a]Utilized both parity and lactation length as covariates.

**Table 4. Effects of Dietary Lysine on Subsequent Farrowing Performance**[a]

| Item | Dietary Lysine, % | | SEM | P< |
|---|---|---|---|---|
| | 1.0 | 1.3 | | |
| Number of sows weaned | 181 | 172 | | |
| Days to return to estrus | 6.03 | 5.85 | .49 | .79 |
| Number of sows rebreed[b] | 131 | 119 | | |
| Number of sows which farrowed | 91 | 95 | | |
| Farrowing rate, % | 71.5 | 76.7 | 4.0 | .35 |
| Number of pigs born per litter | 11.6 | 11.1 | .33 | .29 |
| Number of pigs born alive litter | 10.5 | 10.5 | .29 | .84 |
| Number of pigs born stillborn litter | .89 | .57 | .12 | .06 |
| Number of pigs born mummified litter | .08 | .11 | .04 | .62 |

[a] Utilized parity as a covariate.

[b] Sows were not included if culled for reproductive problems, structure, and age.

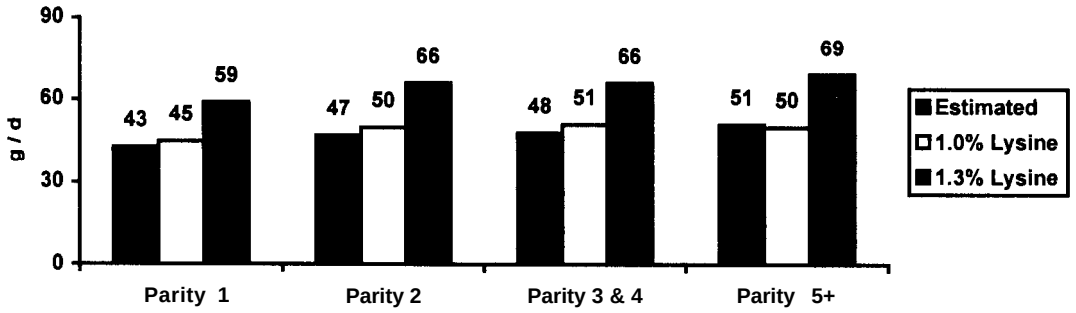



**Figure 1. Comparison of Estimated Lysine Requirement (using equation from Biokyowa) and Actual Lysine Intake of Sows.**

# EFFECTS OF INORGANIC AND ORGANIC ACIDS ON URINE pH IN LACTATING SOWS [1]

***J. M. DeRouchey, J. D. Hancock, R. H. Hines, H. Coa, D. J. Lee, C. A. Maloney, and J. S. Park***

## Summary

Some swine practitioners are advocating the use of dietary acidifiers to reduce urine pH and, thereby, reduce the incidence of urinary tract infections. In our experiment, sows fed an inorganic (phosphoric) acid had lower urine pH than sows fed diets with organic (fumaric, lactic, formic, propionic, and citric) acids. Indeed, the organic acids at 1.5% and 3.0% of the diet increased blood pH and decreased $pCO_2$,indicating that these sows were in a more alkalotic (not acidotic) state.

(Key Words: Sows, Urine pH, Acidification.)

## Introduction

Acidification of nursery diets can enhance piglet growth and efficiency by changing the pH of the intestinal contents. This change in pH of the digesta is thought to inhibit proliferation of pathogenic organisms. In a similar manner, use of acidifiers in gestation and lactation diets has been suggested as a means to lower urine pH, thereby reducing the occurrence of urinary tract disease. This effect has not been well documented, however, and the effects of different types and concentrations of acids in sow diets have not been demonstrated.

## Procedures

On d 110 of gestation, 44 sows were assigned randomly to a corn-soybean meal-based diet (Table 1). Dietary treatments were the basal diet or the basal diet with acid as 1.5 or 3.0% of the formulation. Treatments were phosphoric acid (Kem Gest®); a mixture of fumaric, lactic, propionic, formic, and citric acids (Acid Lac®); and citric acid. Sow and piglet weights were recorded at weaning (d 21), and litter size was standardized by d 2 of lactation. The sows were allowed ad libitium access to feed and water. Venous blood samples were taken from the brachial region on d 10 and analyzed (within 20 minutes) for blood gases and electrolytes. Urine samples (midstream) were collected on d 10 to 12 to determine pH. Response criteria included sow and litter performance and blood and urine chemistry. All data were analyzed with sow as the experimental unit, and orthogonal contrasts were used to separate treatment means.

## Results and Discussion

Sow weights, daily feed intake, and litter performance (Table 2) were similar among the treatments (P>.24). We should note, however, that this experiment was designed to determine the effects of treatments on blood and urine chemistry, especially urine pH. Thus, the number of sows used was too small to draw meaningful conclusions about treatment effects on sow and litter performance.

Sows fed the acid treatments had higher blood pH (P<.10) than sows fed the control (Table 3). Blood pH is controlled by the concentrations of $CO_2$ (carbon dioxide) and

[1]Appreciation is expressed to Dr. Richard Odgaard and Kemin Industries for the acid products (Kem Gest®, Acid Lac®, and citrate) and funding of this project.

$HCO_3^-$ (bicarbonate), which are the main buffering agents in blood. In an alkalotic state, the $pCO_2$ is lowered, and $HCO_3^-$ is raised. In our experiment, the $pCO_2$ (carbon dioxide in the gas phase of blood) tended to be lower (P<.15) for sows fed the acid treatments versus the control, but the amount of $HCO_3^-$ was not affected by treatment (P>.78). Nonetheless, the differences in extracellular $pCO_2$ indicates a shift to intracellular formation of carbonic acid ($H_2CO_3$) from $HCO_3^-$ and $H^+$. This decreases the extracellular $H^+$, thus increasing extracellular pH. This process reduces the amount of free $H^+$, also raising pH of the blood.

Urine pH of sows fed the acidified diets was not different than that of sows fed the control diet (P>.20). However, this was caused by greater urine pH for sows fed the organic acids and lower urine pH of sows fed the inorganic acid (P<.001). This response raises questions about the efficacy of organic acids for acidification of urinary tracts in sows.

The $pO_2$ (mmHg) and $O_2$ saturation (%) are the amount of oxygen in the gas state in blood and the amount of oxygen that is bound to available hemoglobin, respectively. In our experiment, both were in the normal range for lactating sows, and no treatment effect occurred (P>.29).

The amounts of $Na^+$ (P< .12) and $Cl^-$ (P<.05) were increased when acid concentration in the diet was increased, especially for the phosphoric acid and acid mixture treatments (acid mixture vs citric acid x concentration interaction, P<.08). The mechanism for this response was unclear, but an electrolyte balance must be maintained within the blood and explains why $Na^+$ and $Cl^-$ moved together. Concentration of $K^+$ decreased (P<.02) when the concentration of citric acid was increased from 1.5 to 3.0%. Those sows given the 3.0% treatments may have been in a more alkalotic state, because they had the highest urine and blood pHs. A shift of $K^+$ into cells is associated with this condition, thereby lowering its concentration in the blood.

The concentration of $Ca^{++}$ in the blood is a predictor of demineralization in the bones. Normalized $Ca^{++}$ is the concentration that has been adjusted to a blood pH of 7.40, and ionized $Ca^{++}$ concentration is the value at the animal's current blood pH. Ionized $Ca^{++}$ tended to be lower for sows fed inorganic versus organic acids (P<.11) and decreased as acid addition was increased (P<.07). Also, normalized $Ca^{++}$ decreased (P<.07) as acid addition was increased and with acid mixture versus citric acid × concentration (P<.08). These responses indicated less demineralization of bone during lactation when the diet contained inorganic acid and greater concentrations of acid.

Base excess in blood is the number of millimoles of strong acid or base needed to adjust 1 L of blood to pH 7.40. The base excess in extracellular fluid is a value calculated (from base excess in the blood) to estimate base excess in the whole body. No differences were detected among treatments (P>.37) for base excess, and all treatment means were in normal ranges.

In conclusion, the inorganic acid used in our experiment reduced urine pH of sows, whereas the organic acids increased pH.

**Table 1. Basal Diet[a]**

| Ingredient | % |
|---|---|
| Corn | 62.95 |
| Soybean meal (46.5% CP) | 26.98 |
| Corn gluten meal | 2.96 |
| Soy oil | 1.00 |
| Monocalcium phosphate | 2.08 |
| Limestone | 1.24 |
| Acidifier[b] | -- |
| Salt | .50 |
| Vitamin premix | .25 |
| Sow vitamin premix | .25 |
| Trace mineral premix | .15 |
| Antibiotic[c] | .10 |
| Total | 100.00 |

[a]Formulated to 1.0% lysine, 1.0% valine, .95% Ca, .80% P, and 1,462 kcal/lb of ME.
[b]For the other treatments, 1.5% or 3.0% acid product (phosphoric acid was Kem Gest®); the mixture of fumaric, lactic, propionic, formic, and citric acids was Acid Lac®; and citric acid) was added.
[c]Provided 100 g/ton of chlortetracycline.

**Table 2. Inorganic and Organic Acids and Sow and Litter Performance[ab]**

| | | Phosphoric Acid | | Acid Mixture[d] | | Citric Acid | | |
|---|---|---|---|---|---|---|---|---|
| Item[c] | Control | 1.5% | 3.0% | 1.5% | 3.0% | 1.5% | 3.0% | SE[d] |
| No. of sows | 9 | 5 | 3 | 9 | 9 | 5 | 4 | |
| Sow wt at farrowing , lb | 488 | 497 | 471 | 515 | 460 | 498 | 463 | 23 |
| Sow wt at weaning, lb | 472 | 463 | 450 | 493 | 448 | 466 | 430 | 7 |
| ADFI, lb | 14.8 | 15.0 | 15.5 | 14.2 | 14.0 | 15.2 | 13.7 | .7 |
| Initial pigs/litter | 11.6 | 12.0 | 12.3 | 10.8 | 12.0 | 11.4 | 11.5 | .5 |
| Pigs weaned/litter[b] | 10.8 | 10.8 | 10.7 | 9.8 | 10.8 | 9.8 | 10.3 | .5 |
| Initial litter wt, lb[b] | 37 | 37 | 37 | 41 | 39 | 41 | 41 | 2 |
| Litter wt gain, lb[b] | 115 | 111 | 118 | 121 | 119 | 128 | 127 | 7 |

[a]A total of 44 sows (PIC C-22 parities 1 to 4).
[b]Least-square means with initial pigs / litter used as a covariate.
[c]No treatment effect (P>.15).
[d]Mixture of fumaric, lactic, formic, propionic, and citric acid.

**Table 3. Physiological Effects of Inorganic and Organic Acids on Lactating Sows[ab]**

| | | Phosphoric Acid | | Acid Mixture[c] | | Citric Acid | | |
|---|---|---|---|---|---|---|---|---|
| Item | Control | 1.5% | 3.0% | 1.5% | 3.0% | 1.5% | 3.0% | SE |
| Body fluid pH | | | | | | | | |
| Blood | 7.36 | 7.39 | 7.37 | 7.37 | 7.36 | 7.39 | 7.39 | .01 |
| Urine | 6.92 | 6.05 | 6.01 | 6.88 | 7.18 | 7.17 | 7.35 | .10 |
| Blood gases | | | | | | | | |
| $pO_2$, mmHg | 50.5 | 48.2 | 41.5 | 44.6 | 44.2 | 40.6 | 41.0 | 2.9 |
| $O_2$ saturation, % | 74.0 | 77.3 | 68.0 | 70.3 | 69.4 | 71.5 | 72.2 | 2.7 |
| $pCO_2$, mmHg | 54.9 | 50.0 | 51.6 | 52.8 | 53.0 | 50.6 | 51.4 | 1.6 |
| $tCO_2$, mmol/L | 31.6 | 31.4 | 30.7 | 31.5 | 31.1 | 31.2 | 31.9 | .7 |
| $HCO_3^-$, mmol/L | 30.1 | 30.0 | 29.2 | 30.1 | 29.6 | 29.8 | 30.5 | .7 |
| BE-ECF, mmol/L[d] | 4.9 | 5.4 | 4.2 | 5.2 | 4.6 | 5.1 | 5.8 | .8 |
| BE-BLD, mmol/L[e] | 4.8 | 5.5 | 4.3 | 5.2 | 4.6 | 5.1 | 5.8 | .7 |
| Blood electrolytes | | | | | | | | |
| $Na^+$, mmol/L | 145.3 | 144.8 | 145.3 | 145.7 | 146.8 | 145.0 | 145.8 | .5 |
| $K^+$, mmol/L | 4.6 | 4.9 | 5.1 | 4.8 | 4.8 | 5.1 | 4.3 | .2 |
| $Cl^-$, mmol/L | 103.2 | 103.4 | 105.0 | 103.3 | 105.1 | 103.8 | 103.5 | .1 |
| Electrolyte balance | 46.7 | 46.3 | 45.4 | 47.2 | 46.5 | 46.3 | 46.6 | -- |
| Ca++, mg/dL | | | | | | | | |
| ionized | 5.2 | 4.4 | 5.0 | 5.2 | 5.2 | 5.1 | 4.9 | .2 |
| normalized | 5.2 | 5.1 | 5.0 | 5.2 | 5.2 | 5.2 | 5.0 | .1 |

[a]A total of 44 (PIC-22 parities 1 to 4).
[b]Urine collected on d 10 to 12; Blood collected on d 10.
[c]Mixture of fumaric, lactic, formic, propionic, and citric acids.
[d]Base excess in extracellular fluid.
[e]Base excess in blood.

**Table 4. Physiological Effects of Inorganic and Organic Acids on Lactating Sows[a]**

| | Contrasts, P <[b] | | | | | |
|---|---|---|---|---|---|---|
| Item | Control vs others | Inorganic vs organic | Acid mixture[c] vs citric acid | 1.5% vs 3.0% acid concentration | Inorganic vs organic acid × concentration | Acid mixture vs citric acid × concentration |
| Body fluid pH | | | | | | |
| Blood | .10 | -- | -- | -- | -- | -- |
| Urine | -- | .001 | .07 | .15 | -- | -- |
| Blood gases | -- | -- | -- | -- | -- | -- |
| $pO_2$, mmHg | -- | .14 | -- | -- | -- | -- |
| $O_2$ saturation, % | | | | | | |
| $pCO_2$, mmHg | .15 | -- | -- | -- | -- | -- |
| $tCO_2$, mmol/L | -- | .05 | -- | -- | .09 | -- |
| $HCO_3^-$, mmol/L | -- | -- | -- | -- | -- | -- |
| BE-ECF, mmol/L[d] | -- | -- | -- | -- | -- | -- |
| BE-BLD, mmol/L[e] | -- | -- | -- | -- | -- | -- |
| Blood electrolytes | | | | | | |
| $Na^+$, mmol/L | -- | -- | -- | .12 | -- | -- |
| $K^+$, mmol/L | -- | -- | -- | -- | .15 | .02 |
| $Cl^-$, mmol/L | -- | -- | .08 | .05 | -- | .08 |
| Ca++, mg/dL | | | | | | |
| ionized | -- | .11 | -- | -- | .07 | -- |
| normalized | -- | -- | -- | .07 | -- | .10 |

[a]A total of 44 (PIC C-22 parities 1 to 4).
[b]Dashes indicate P>.15.
[c]Mixture of fumaric, lactic, formic, propionic, and citric acids.
[d]Base excess in extracellular fluid.
[e]Base excess in blood.

# OVULATION AND FERTILIZATION RATE OF GILTS PROVIDED ADDITIONAL L-CARNITINE AND CHROMIUM NICOTINATE [1]

*C. J. Samland, R. E. Musser, J. K. Peters, J. T. Sawyer, K. Q. Owen [2], and D. L. Davis*

## Summary

We determined the effects of L-carnitine (200 ppm), chromium nicotinate (CrNic; 200 ppb), a combination of L-carnitine and CrNic, or flushing (11 lb/d of complete diet fed for 14 d prior to breeding) on ovulation and fertilization rates in gilts. All gilts (n = 105) were administered PG600 to aid in the synchronization of estrus. After detection of estrus, gilts were assigned randomly to dietary treatments and were fed at 4 lb/d with the exception of gilts on the flushing treatment. Treatments were continued until breeding at the third estrus. Surgeries were performed on d 2 to 3 after third estrus was detected to determine ovulation rate and collect embryos and unfertilized eggs. An increase ($P<.10$) in ovulation rate was observed for gilts in the flushing or L-carnitine treatment. Supplemental L-carnitine decreased ($P = .10$) fertilization rate of embryos recovered. No differences were observed for number of empty zonae or number of unclassifiable eggs. Increased ovulation rates for L-carnitine-treated gilts warrants further evaluation to determine whether L-carnitine increases number of pigs farrowed.

(Key Words: L-Carnitine, Chromium, Ovulation, Gilts.)

## Introduction

An important factor influencing the productivity of swine operations is the rate of reproduction. Management for improved reproductive rates includes consideration of the interactions of growth and metabolism with ovarian function and supplying adequate energy to achieve full reproductive performance. Increased insulin in peripheral circulation has been shown to increase maturation of ovarian follicles and ovulation rate. These observations may explain effects of flushing, which requires increasing daily feed intake of gilts for approximately 2 weeks prior to breeding and increases ovulation rate and potentially increases litter size.

Insulin and IGF-1 are important regulators of growth, metabolism, and reproductive function. L-carnitine and chromium are two regulatory nutrients that influence insulin. Therefore, they may affect the number of follicles maturing and ovulating at estrus. Previously, we reported the addition of L-carnitine to the gestation diet caused an increase in circulating insulin and IGF-1. Chromium potentiates insulin action by increasing the cellular uptake of glucose and intracellular carbohydrate and lipid metabolism. Chromium is available in two forms, chromium picolinate and chromium nicotinate, and both are reported to increase insulin uptake.

Based on these considerations, we evaluated the effects of L-carnitine and chromium nicotinate (CrNic) on ovulation and fertilization rates in gilts. The ability of these nutrients to influence insulin suggests that they may affect the number of follicles maturing and ovulating at estrus. Because L-carnitine and chromium affect energy metabolism by

[1]The authors thank Lonza Inc., Fair Lawn, NJ for partial funding of this experiment.
[2]Lonza, Inc., Fair Lawn, NJ.

different mechanisms, they potentially could act synergistically to promote follicular growth and ovulation rate.

## Procedures

A total of 105 gilts (PIC C22 × 326) was used to evaluate the effects of additional dietary L-carnitine (200 ppm) and CrNic (200 ppb) on ovulation and fertilization rates. A positive control was provided by feeding gilts 11 lb/d of complete diet (flushing) for 14 d before estrus. Gilts were fed a .65% lysine diet, with the additions of L-carnitine or CrNic replacing corn. All gilts were fed 4 lb/d of diet with or without the various treatments, and gilts in the flushing treatment received a total of 11 lb/d for the 2 weeks prior to expected estrus. That treatment was included to evaluate the potential for nutrients to increase ovulation rate under our experimental conditions.

At approximately 250 lb body weight, gilts were moved to outside pens and monitored for estrus using an epididymectomized boar. After detection of estrus (d 0), gilts were assigned to dietary treatments and fed individually. The flushing treatment began on approximately d 6 of the second estrous cycle and continued through third estrus. Gilts were inseminated on the first (d 0) and second days of estrus.

On d 2 or 3 after breeding, gilts were anesthetized, and their reproductive tract was exposed by mid-ventral laparotomy. Number of corpora hemorrhagica (forming corpora lutea) was determined to establish ovulation rate, and embryos were recovered by flushing the oviducts and uterus. Cleaved eggs were considered fertilized, and uncleaved eggs were stained for evidence of fertilization and nuclear maturation of the oocyte.

Data were analyzed as a 2 × 2 factorial with a positive control. Day of surgery was used as a covariate in the analysis of data for all responses but ovulation rate.

## Results

No L-carnitine × CrNic interactions were observed. An increase in ovulation rate was observed for gilts on either the flushing or added L-carnitine (P=.06) treatments (Table 1). No differences were observed for percentage of embryos recovered. However, there were tendencies for fewer eggs recovered from sows fed additional CrNic (P=.08), and a higher number of eggs recovered from gilts fed the flushing treatment (P=.07). The reduction in eggs recovered in the CrNic treatment seemed to be due to numerically fewer ovulations.

A decreased (P=.04) percentage fertilization of eggs was observed when gilts were fed added L-carnitine. No differences were observed for number of empty zonae or number of unclassified embryos. The unclassified embryos were single-cell eggs that either were lost during staining or damaged such that fertilization status could not be determined.

## Discussion

Flushing gilts with additional feed is expected to increase ovulation rate and may increase number of pigs born alive per litter, although the latter trait may not be improved consistently. These increases may result in part from increased insulin and/or IGF-1 secretion because of increased feed intake.

Added L-carnitine also has been shown to increase the number of pigs born alive. Our data suggest that this effect may be due to increased ovulation rate. Further work is needed to determine the optimum dose of L-carnitine added to the diet and the potential for this treatment to affect litter size in pigs.

**Table 1. Ovulation Rates and Characteristics of Eggs Recovered as Affected by L-Carnitine and(or) Chromium Nicotinate**

| Item | Control | Carnitine (200 ppm) | CrNic (200 ppb) | Carnitine + CrNic | Flushing (11 lb/d) | Probability (P <) Carnitine | CrNic | Carnitine + CrNic | Flushing | SEM |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of gilts | 20 | 20 | 20 | 22 | 23 | | | | | |
| Day of surgery | 2.46 | 2.22 | 2.42 | 2.33 | 2.44 | .11 | .74 | .49 | .50 | .12 |
| Avg. no. corpora hemorrhagica | 15.2 | 15.6 | 13.9 | 15.5 | 17.1 | .06 | .20 | .28 | .01 | .53 |
| Avg. no. eggs recovered[a] | 13.8 | 13.9 | 11.9 | 13.4 | 14.6 | .24 | .08 | .30 | .07 | .72 |
| Recovery rate, % [a] | 91 | 90 | 85 | 86 | 85 | .98 | .21 | .77 | .36 | 3.5 |
| Avg. no. fertilized eggs[a] | 12.9 | 11.9 | 11.2 | 11.2 | 11.9 | .62 | .18 | .61 | .95 | 1.0 |
| Percent fertilized, % [a] | 95 | 84 | 100 | 85 | 84 | .03 | .41 | .45 | .32. | 7.7 |
| Avg. no. unfertilized eggs [a] | .62 | 1.91 | .30 | 1.37 | 1.69 | .09 | .52 | .87 | .38 | .71 |
| Avg. no. unclassified eggs [a] | .19 | .08 | .17 | .89 | .48 | .40 | .27 | .69 | .25 | .37 |
| Avg. no. empty zonae [a] | .01 | .05 | .19 | .10 | .02 | .75 | .15 | .40 | .44 | .09 |

[a]Data were analyzed using day of surgery as a covariate.

# EVALUATION OF A HIGH-PROTEIN WHEY PROTEIN CONCENTRATE AND SPRAY-DRIED ANIMAL PLASMA ON GROWTH PERFORMANCE OF WEANLING PIGS [1]

*G. S. Grinstead, R. D. Goodband, J.L. Nelssen, M. D. Tokach [2], B. Reibold, J. T. Sawyer, and M. Molitor [3]*

## Summary

Results of these studies suggest that experimental high molecular weight, whey protein concentrate can be an effective replacement for spray-dried animal plasma in diets for weanling pigs. Increasing spray-dried animal plasma improved ADG and ADFI quadratically, with the maximum response observed with 2.5% in 21-d-old pigs or 5.0% in 12-d-old pigs. The specialty whey protein concentrate fed from d 0 to 14 after weaning resulted in similar responses as spray-dried animal plasma fed during the same period and may be an effective alternative.

(Key Words: Starter Pigs, Spray-Dried Animal Plasma, High-Protein Whey Protein Concentrate.)

## Introduction

Whey protein concentrate has been established as an excellent protein source in diets for weanling pigs. Specialty high molecular weight, whey protein concentrate (Foremost Farms) contains twice the protein and amino acids as conventional whey protein concentrate. In addition, the manufacturing process also concentrates the immunoglobulin fraction. Because of the immunoglobulins contained in spray-dried animal plasma may be responsible for its positive effects on weanling pig growth, specialty whey protein concentrate may be a potential alternative.

In the 1997 Kansas State University Swine Day Report of Progress, we evaluated the use of specialty whey protein concentrate in weanling pig diets. However, we observed few positive responses to increasing high molecular weight, whey protein concentrate or spray-dried animal plasma, possibly suggesting that our control diet was already adequate for the age, weight, and health status of the pigs. Therefore, the objective of these experiments was to revaluate experimental whey protein concentrate as a replacement for spray-dried animal plasma in younger pigs with less complex diets.

## Procedures

**Animals and Housing.** For Exps. 1 and 2, pigs were blocked by weight, equalized for sex and ancestry, and allotted randomly to one of five experimental treatments. Each treatment had six pigs per pen and six pigs per treatment. The trials were divided into two phases with the pelleted, experimental diets fed from d 0 to 14 after weaning. All diets were formulated to contain 1.5% or 1.4% lysine (Exps. 1 and 2, respectively), .9% Ca, .8% P. Additional DL-methionine was used to maintain a constant level of methionine in all diets. From d 14 to 35 after weaning, a common corn-soybean meal diet containing 10% dried whey and 2.5%

[1]The authors thank Foremost Farms USA, Sauk City, WI for providing the high molecular weight, whey protein concentrate used in these experiments and Adam McNess and Eichman Brothers, St. George, KS for the use of facilities and animals in Exps. 3 and 4.

[2]Northeast Area Extension Office, Manhattan, KS.

[3]Foremost Farms USA, Sauk City, WI.

spray-dried blood meal was fed in a meal form. The common diet was formulated to contain 1.35% lysine, .9% Ca, and .8% P (Table 2). Pigs were housed at the Kansas State University Swine Teaching and Research Center in an environmentally controlled nursery in 5 x 5 ft. pens and were provided ab libitum access to feed and water. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearances on d 7,14, 21, 28, and 35 after weaning.

In Exps. 3 and 4, pigs were blocked by initial weight and allotted randomly to one of five dietary treatments. Each treatment had eight or nine pigs per pen and seven replications per treatment. The trials were divided into two phases with the pelleted experimental diets fed from d 0 to 14 after weaning. All diets fed during this period contained at least 2.5% spray-dried animal plasma and were formulated to contain 1.7% lysine, .9% Ca, .8% P, and .48% methionine. From d 14 to 28 after weaning, the same diet from Exps. 1 and 2 was used. Pigs were housed on a commercial operation in an environmentally controlled nursery in 5 × 5 ft pens and were provided ad libitum access to feed and water.

Chemical compositions of the experimental specialty whey protein concentrate and spray-dried animal plasma are presented in Table 1.

**Experiment 1.** A total of 180 weanling pigs with an average weight of 12.8 lb and 18 to 21 days of age was used. Dietary treatments were based on a corn-soybean meal control diet containing 20% dried whey and 2.5% spray-dried blood meal. Spray-dried animal plasma (2.5 or 5.0%) or specialty whey protein concentrate (2.5 or 5.0%) was substituted for soybean meal, on an equal lysine basis, in the control diet to create the additional experimental treatments (Table 2). Diets were formulated using the analyzed values of the specialty whey protein concentrate and spray-dried animal plasma.

**Experiment 2.** A total of 180 weanling pigs with an initial average weight of 11.1 lb and 16 to 18 d of age was used. Diets fed in this experiment were based on a corn-soybean meal control diet that contained less specialty protein sources than the basal diet of Exp. 1. They contained 15% dried whey compared to 20% dried whey in Exp.1. Spray-dried animal plasma (2.5 or 5.0%) or high protein, whey protein concentrate (2.5 or 5.0%) was substituted for soybean meal, on an equal lysine basis, in the control diet to create the additional experimental treatments (Table 3).

**Table 1. Compositions of High Protein, Whey Protein Concentrate and Spray-Dried Animal Plasma[a]**

| Item , % | Whey Protein Concentrate | Animal Plasma |
|---|---|---|
| Protein | 73.18 | 70.00 |
| Fat | 6.00 | 2.00 |
| Ash | 6.50 | 13.00 |
| Amino acids | | |
| Arginine | 2.32 | 5.30 |
| Cystine | 1.68 | 2.50 |
| Histidine | 1.49 | 2.80 |
| Isoleucine | 4.15 | 1.96 |
| Leucine | 7.43 | 5.56 |
| Lysine | 6.81 | 6.80 |
| Methionine | 1.52 | 0.53 |
| Phenylalanine | 2.67 | 4.10 |
| Threonine | 4.64 | 4.13 |
| Tryptophan | 1.63 | 1.33 |
| Tyrosine | 2.34 | 3.90 |
| Valine | 4.42 | 4.12 |

[a]Analyzed values expressed on an as-fed basis.

**Experiment 3.** A total of 305 weanling pigs with an average initial weight of 9.0 lb and 12 to 13 d of age was used. Dietary treatments were based on a corn-soybean meal control diet containing 25% dried whey, 6.0% fish meal, 5.0% lactose, 2.5% spray-dried animal plasma, and 1.75% spray-dried blood meal. Additional spray-dried animal plasma (2.5 or 5.0%) or specialty whey protein concentrate (2.5 or 5.0%) was substituted for soybean meal, on an equal lysine basis, in the control diet to create the additional experimental treatments (Table 4).

**Experiment 4.** A total of 320 weanling pigs with an average initial weight of 9.2 lb and 12 to 13 d of age was used. This experiment was designed to compare pig performance when experimental whey protein concentrate replaced increasing amounts of spray-dried animal plasma fed from d 0 to 14 after weaning. Dietary treatments were based on a corn-soybean meal control diet containing 25% dried whey, 6.0% fish meal, 5.0% lactose, 6.7% spray-dried animal plasma, and 1.75% spray-dried blood meal. High protein, whey protein concentrate was substituted for spray-dried animal plasma on an equal lysine basis. It replaced 25, 50, 75, and 100% of the spray-dried animal plasma in the control diet to provide the additional experimental treatments (Table 5).

## Results and Discussion

In Exp. 1, from d 0 to 7 after weaning, no differences in ADG, ADFI, or F/G were observed for pigs fed any of the experimental treatments (Table 6). However, ADFI tended to increase numerically then decrease with increasing spray-dried animal plasma (quadratic, P = .12). From d 7 to 14 and d 0 to 14 after weaning, no differences were observed for pigs fed either of the experimental treatments.

From d 14 to 35 after weaning (pigs were fed a common diet) and for cumulative performance, F/G tended to increase numerically then decrease with increasing spray-dried animal plasma fed from d 0 to 14 (quadratic, P=.10, Table 6). However, no differences in ADG or ADFI were observed in pigs fed any of the different protein sources from d 0 to 14.

As with our previous experiment reported in the 1997 Kansas State University Swine Day Report of Progress, we believe that because of the high-health status, weight, and age of the pigs at weaning, the diets were likely too complex. Thus, we observed few benefits from the increasing spray-dried animal plasma or high molecular weight, whey protein concentrate. Therefore, we conducted a second experiment, in which we further reduced the complexity of the control diet and decreased the age at weaning.

In Exp. 2, from d 0 to 7 after weaning, ADG increased with increasing spray-dried animal plasma and specialty whey protein concentrate (linear, P=.002 and .02, respectively, Table 7). Average daily feed intake also increased (linear, P=.04) with increasing spray-dried animal plasma but was unchanged for pigs fed specialty whey protein concentrate. Feed efficiency was improved for pigs fed increasing spray-dried animal plasma (linear, P=.007) or specialty whey protein concentrate (linear, P =.002). Pigs fed specialty whey protein concentrate had the best feed efficiency during this period.

From d 0 to 14 after weaning, ADG, ADFI, and F/G improved (linear, P=.002, .04, and .02 respectively) with increasing spray-dried animal plasma (Table 7). Increasing specialty whey protein concentrate improved ADG (linear, P=.001) and F/G, (linear, P=.003), but ADFI was unchanged. From d 14 to 35 or d 0 to 35 after weaning, no differences were observed in pigs previously fed any of the experimental treatments.

Based on the results in Exp.2, with younger and lighter pigs, we conducted Exps. 3 and 4 on a commercial facility to further validate our findings. In Exp. 3, from d 0 to 7 after weaning, ADG tended to increase then decrease with increasing spray-dried animal plasma (quadratic, P=.16, Table 8). This response to ADG also was observed with increasing specialty whey protein concentrate (quadratic, P=.04). Average daily feed intake increased linearly with increasing spray-dried animal plasma (P=.04), although actual intake values were identical. Feed efficiency was not affected by spray-dried animal plasma. Increasing specialty whey protein concentrate increased then decreased ADFI and F/G (quadratic, P=.05 and .09, respectively).

From d 0 to 14 after weaning, ADG, ADFI, and F/G increased quadratically with increasing spray-dried animal plasma (P=.003, .04, and .02, respectively), with pigs fed 5.0% spray-dried animal plasma

having the best ADG. Average daily gain (quadratic, P=.07) tended to increase then decrease, whereas ADFI (linear, P=.09) tended to increase with increasing specialty whey protein concentrate. Feed efficiency was not affected.

From d 14 to 28 after weaning, ADG (P=.11) and ADFI (P=.04) tended to numerically decrease linearly in pigs fed increasing spray-dried animal plasma fed from d 0 to 14 after weaning. However, feed efficiency was not affected. No differences in ADG, ADFI, or F/G were observed from d 14 to 28 after weaning in pigs fed the specialty whey protein concentrate.

For the cumulative period, d 0 to 28 after weaning, no differences in ADG or ADFI were observed in pigs fed either increasing spray-dried animal plasma or high molecular weight, whey protein concentrate from d 0 to 14 after weaning. Pigs previously fed increasing specialty whey protein concentrate from d 0 to 14 after weaning had improved F/G (quadratic, P=.03).

In Exp. 4 from d 0 to 7 after weaning, as specialty whey protein concentrate replaced increasing amounts of spray-dried animal plasma, ADG increased then decreased (quadratic, P<.10, Table 9). Average daily feed intake and F/G was not affected by increasing specialty whey protein concentrate. However, pigs fed 3.35% specialty whey protein concentrate and 3.35% spray-dried animal plasma had numerically the greatest ADG and the best feed efficiency during the first week after weaning.

From d 0 to 14 after weaning, ADG and ADFI increased then decreased with increasing specialty whey protein concentrate (quadratic, P<.04, and .09, respectively). Feed efficiency was not affected by specialty whey protein concentrate. During this period, pigs fed the diet containing 5.0% specialty whey protein concentrate and 1.7% spray-dried animal plasma, had numerically the highest ADG and ADFI of any experimental treatments.

From d 14 to 28 after weaning, no differences in ADG, ADFI, or F/G were observed when pigs were fed a common diet. This pattern also was observed for cumulative performance, d 0 to 28 after weaning.

Evaluation of all four studies showed that increasing spray-dried animal plasma from 2.5 to 5.0% in 21-d-old pigs or from 5.0 to 7.5% in 12-d-old pigs did not further improve growth performance. We also can conclude that pigs fed specialty whey protein concentrate demonstrated similar growth performance compared to pigs fed similar amounts of spray-dried animal plasma. Therefore, specialty whey protein concentrate can be an effective replacement for spray-dried animal plasma in diets for early-weaned pigs.

**Table 2. Compositions of Diets (Exp.1)**

| | | Spray-Dried Animal Plasma, %[a] | | Whey Protein Concentrate, %[a] | | |
|---|---|---|---|---|---|---|
| Ingredients, % | Control[a] | 2.5 | 5.0 | 2.5 | 5.0 | Day 14-35[b] |
| Corn | 37.86 | 41.27 | 44.68 | 41.24 | 44.62 | 51.87 |
| Soybean meal | 29.87 | 23.94 | 18.01 | 23.94 | 18.00 | 26.85 |
| Dried whey | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 10.00 |
| Soybean oil | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 4.00 |
| Monocalcium phosphate | 1.62 | 1.59 | 1.60 | 1.74 | 1.85 | 1.65 |
| Whey protein concentrate | -- | -- | -- | 2.50 | 5.00 | -- |
| Spray-dried animal plasma | -- | 2.50 | 5.00 | -- | -- | -- |
| Spray-dried blood meal | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 |
| Antibiotic [c] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Limestone | .89 | .94 | .98 | .84 | .79 | .98 |
| Zinc oxide | .38 | .38 | .38 | .38 | .38 | .25 |
| Vitamin premix | .25 | .25 | .25 | .25 | .25 | .25 |
| Salt | .20 | .20 | .20 | .20 | .20 | .25 |
| Trace mineral premix | .15 | .15 | .15 | .15 | .15 | .15 |
| L-Lysine HCl | .15 | .15 | .15 | .15 | .15 | .15 |
| DL-Methionine | .14 | .14 | .15 | .12 | .11 | .10 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

[a]Diets were formulated to contain 1.5% lysine, .42% methionine, .9% Ca, .8% P and fed from d 0 to 14 after weaning.
[b]Diet was formulated to contain 1.35% lysine .38% methionine, .9% Ca, .8% P and fed to all pigs from d 14 to 35, or 14 to 28 after weaning in Exps.1, 2, 3, and 4.
[c]Provided 50 g/ton carbadox.

**Table 3. Compositions of Diets (Exp. 2)**

| | | Spray-Dried Animal Plasma, % [a] | | Whey Protein Concentrate, % [a] | |
|---|---|---|---|---|---|
| Ingredients, % | Control [a] | 2.5 | 5.0 | 2.0 | 5.0 |
| Corn | 40.84 | 44.24 | 47.65 | 44.22 | 47.59 |
| Soybean meal | 34.36 | 28.43 | 22.50 | 28.42 | 22.49 |
| Dried whey | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 |
| Soybean oil | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Monocalcium phosphate | 1.66 | 1.64 | 1.60 | 1.77 | 1.88 |
| Whey protein concentrate | -- | -- | -- | 2.50 | 5.00 |
| Spray-dried animal plasma | -- | 2.50 | 5.00 | -- | -- |
| Spray-dried blood meal | -- | -- | -- | -- | -- |
| Antibiotic [b] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Limestone | .95 | 1.00 | 1.05 | .90 | .85 |
| Zinc oxide | .38 | .38 | .38 | .38 | .38 |
| Vitamin premix | .25 | .25 | .25 | .25 | .25 |
| Salt | .20 | .20 | .20 | .20 | .20 |
| Trace mineral premix | .15 | .15 | .15 | .15 | .15 |
| L-Lysine HCl | .15 | .15 | .15 | .15 | .15 |
| DL-methionine | .06 | .08 | .10 | .06 | .06 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

[a]Diets were formulated to contain 1.4% lysine, .42% methionine, .9% Ca, .8% P and fed from d 0 to 14 after weaning.
[b]Provided 50 g/ton carbadox.

**Table 4. Compositions of Diets (Exp. 3)**

| | | Spray-Dried Animal Plasma, % [a] | | Whey Protein Concentrate, % [a] | |
|---|---|---|---|---|---|
| Ingredients, % | Control [a] | 5.0 | 7.5 | 2.5 | 5.0 |
| Corn | 27.82 | 31.23 | 34.65 | 31.20 | 34.59 |
| Dried whey | 25.00 | 25.00 | 25.00 | 25.00 | 25.00 |
| Soybean meal | 22.44 | 16.51 | 10.57 | 16.50 | 10.56 |
| Soybean oil | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| Fish meal | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| Lactose | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Spray-dried animal plasma | 2.50 | 5.00 | 7.50 | 2.50 | 2.50 |
| Whey protein concentrate | -- | -- | -- | 2.50 | 5.00 |
| Spray-dried blood meal | 1.75 | 1.75 | 1.75 | 1.75 | 1.75 |
| Antibiotic [b] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Monocalcium phosphate | .82 | .78 | .75 | .93 | 1.05 |
| Limestone | .40 | .45 | .49 | .35 | .30 |
| Zinc oxide | .38 | .38 | .38 | .38 | .38 |
| Vitamin premix | .25 | .25 | .25 | .25 | .25 |
| Salt | .20 | .20 | .20 | .20 | .20 |
| Trace mineral premix | .15 | .15 | .15 | .15 | .15 |
| L-Lysine HCl | .15 | .15 | .15 | .15 | .15 |
| DL-Methionine | .15 | .16 | .16 | .14 | .13 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

[a]Diets were formulated to contain 1.7% lysine, .48% methionine, .9% Ca, .8% P and fed from d 0 to 14 after weaning.
[b]Provided 50 g/ton carbadox.

**Table 5. Compositions of Diets (Exp. 4)**

| | Animal Plasma:Whey Protein Concentrate, % [a] | | | | |
|---|---|---|---|---|---|
| Ingredients, % | 6.7:0 | 5.0:1.7 | 3.35:3.35 | 1.7:5.0 | 0:6.7 |
| Corn | 33.56 | 33.55 | 33.52 | 33.50 | 33.48 |
| Soybean meal | 12.47 | 12.47 | 12.47 | 12.47 | 12.47 |
| Dried whey | 25.00 | 25.00 | 25.00 | 25.00 | 25.00 |
| Soybean oil | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| Fish meal | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| Lactose | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Whey protein concentrate | -- | 1.70 | 3.35 | 5.00 | 6.70 |
| Spray-dried animal plasma | 6.70 | 5.00 | 3.35 | 1.70 | -- |
| Spray-dried blood meal | 1.75 | 1.75 | 1.75 | 1.75 | 1.75 |
| Antibiotic [b] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Monocalcium phosphate | .76 | .86 | .96 | 1.06 | 1.16 |
| Limestone | .47 | .41 | .35 | .28 | .22 |
| Zinc oxide | .38 | .38 | .38 | .38 | .38 |
| Vitamin premix | .25 | .25 | .25 | .25 | .25 |
| Salt | .20 | .20 | .20 | .20 | .20 |
| Trace mineral premix | .15 | .15 | .15 | .15 | .15 |
| L-Lysine HCl | .15 | .15 | .15 | .15 | .15 |
| DL-methionine | .15 | .13 | .12 | .11 | .10 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

[a]Diets were formulated to contain 1.7% lysine, .48% methionine, .9% Ca, .8% P and fed from d 0 to 14 after weaning.
[b]Provided 50 g/ton carbadox.

**Table 6. Effects of Increasing High Molecular Weight, Whey Protein Concentrate and Animal Plasma Fed from d 0 to 14 after Weaning on Pig Performance (Exp. 1)[a]**

| | | Added Spray-Dried Animal Plasma, % | | Whey Protein Concentrate, % | | | Animal Plasma | | Whey Protein | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | Control | 2.5 | 5.0 | 2.5 | 5.0 | SEM | Linear | Quad | Linear | Quad |
| Day 0 to 7 | | | | | | | | | | |
| ADG, lb | .68 | .74 | .70 | .74 | .72 | .029 | .65 | .22 | .42 | .27 |
| ADFI, lb | .62 | .68 | .63 | .65 | .63 | .028 | .83 | .12 | .95 | .44 |
| F/G | .91 | .93 | .90 | .88 | .87 | .024 | .79 | .57 | .25 | .69 |
| Day 7 to 14 | | | | | | | | | | |
| ADG, lb | .93 | .94 | .97 | .92 | .92 | .039 | .49 | .78 | .83 | .99 |
| ADFI, lb | 1.07 | 1.10 | 1.12 | 1.08 | 1.01 | .030 | .26 | .88 | .16 | .24 |
| F/G | 1.16 | 1.18 | 1.17 | 1.18 | 1.11 | .047 | .82 | .82 | .44 | .40 |
| Day 0 to 14 | | | | | | | | | | |
| ADG, lb | .81 | .84 | .83 | .83 | .82 | .026 | .44 | .63 | .77 | .54 |
| ADFI, lb | .85 | .89 | .88 | .87 | .82 | .023 | .39 | .30 | .37 | .22 |
| F/G | 1.05 | 1.07 | 1.06 | 1.05 | 1.00 | .024 | .90 | .71 | .16 | .55 |
| Day 14 to 35 | | | | | | | | | | |
| ADG, lb | 1.34 | 1.36 | 1.33 | 1.34 | 1.31 | .030 | .85 | .59 | .42 | .77 |
| ADFI, lb | 2.04 | 2.12 | 2.01 | 2.05 | 2.01 | .049 | .70 | .13 | .68 | .76 |
| F/G | 1.52 | 1.56 | 1.51 | 1.53 | 1.54 | .023 | .76 | .10 | .54 | .98 |
| Day 0 to 35 | | | | | | | | | | |
| ADG, lb | 1.13 | 1.15 | 1.13 | 1.13 | 1.11 | .025 | .85 | .55 | .63 | .64 |
| ADFI, lb | 1.56 | 1.63 | 1.56 | 1.57 | 1.53 | .035 | .92 | .12 | .56 | .55 |
| F/G | 1.39 | 1.42 | 1.37 | 1.39 | 1.38 | .018 | .63 | .10 | .83 | .84 |

[a]A total of 180 weanling pigs (initially 12.8 lb and 18 to 20 d of age) with six pigs per pen and six replications per treatment.

**Table 7. Effects of Increasing High Molecular Weight, Whey Protein Concentrate and Animal Plasma Fed from d 0 to 14 after Weaning on Pig Performance (Exp. 2)[a]**

| | | Added Spray-Dried Animal Plasma, % | | Whey Protein Concentrate, % | | | Animal Plasma | | Whey Protein | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | Control | 2.5 | 5.0 | 2.5 | 5.0 | SEM | Linear | Quad | Linear | Quad |
| Day 0 to 7 | | | | | | | | | | |
| ADG, lb | .38 | .47 | .53 | .49 | .50 | .031 | .002 | .72 | .02 | .19 |
| ADFI, lb | .49 | .52 | .59 | .52 | .52 | .031 | .04 | .68 | .50 | .78 |
| F/G | 1.32 | 1.12 | 1.10 | 1.05 | 1.05 | .052 | .007 | .22 | .002 | .05 |
| Day 7 to 14 | | | | | | | | | | |
| ADG, lb | .62 | .68 | .74 | .68 | .72 | .034 | .02 | .98 | .05 | .82 |
| ADFI, lb | .83 | .87 | .91 | .87 | .82 | .036 | .14 | .89 | .82 | .29 |
| F/G | 1.36 | 1.27 | 1.23 | 1.29 | 1.15 | .067 | .17 | .81 | .04 | .70 |
| Day 0 to 14 | | | | | | | | | | |
| ADG, lb | .50 | .58 | .64 | .59 | .61 | .027 | .002 | .84 | .009 | .35 |
| ADFI, lb | .66 | .70 | .75 | .67 | .67 | .027 | .04 | .75 | .82 | .40 |
| F/G | 1.34 | 1.21 | 1.17 | 1.19 | 1.11 | .047 | .02 | .48 | .003 | .51 |
| Day 14 to 35 | | | | | | | | | | |
| ADG, lb | 1.31 | 1.23 | 1.28 | 1.19 | 1.31 | .036 | .64 | .16 | .90 | .01 |
| ADFI, lb | 1.81 | 1.83 | 1.86 | 1.76 | 1.83 | .038 | .35 | .89 | .68 | .18 |
| F/G | 1.39 | 1.48 | 1.45 | 1.49 | 1.39 | .044 | .32 | .23 | .92 | .09 |
| Day 0 to 35 | | | | | | | | | | |
| ADG, lb | .97 | .95 | 1.01 | .94 | 1.02 | .028 | .27 | .32 | .22 | .12 |
| ADFI, lb | 1.32 | 1.35 | 1.39 | 1.31 | 1.34 | .030 | .13 | .82 | .70 | .50 |
| F/G | 1.37 | 1.42 | 1.37 | 1.40 | 1.32 | .037 | .96 | .38 | .32 | .23 |

[a]A total of 180 weanling pigs (initially 11.1 lb and 16 to 18 d of age) with six pigs per pen and six replications per treatment.

**Table 8. Effects of Increasing High Molecular Weight, Whey Protein Concentrate and Animal Plasma Fed from d 0 to 14 after Weaning on Pig Performance (Exp. 3)** [a]

| | | Added Spray-Dried Animal Plasma, % | | Whey Protein Concentrate, % | | | Animal Plasma | | Whey Protein | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | Control | 2.5 | 5.0 | 2.5 | 5.0 | SEM | Linear | Quad | Linear | Quad |
| Day 0 to 7 | | | | | | | | | | |
| ADG, lb | .22 | .26 | .25 | .28 | .25 | .02 | .25 | .16 | .44 | .04 |
| ADFI, lb | .27 | .31 | .31 | .32 | .30 | .01 | .04 | .14 | .23 | .05 |
| F/G | 1.32 | 1.23 | 1.27 | 1.16 | 1.24 | .06 | .63 | .39 | .57 | .09 |
| Day 7 to 14 | | | | | | | | | | |
| ADG, lb | .57 | .64 | .55 | .60 | .61 | .02 | .42 | .002 | .33 | .44 |
| ADFI, lb | .61 | .65 | .60 | .65 | .67 | .02 | .83 | .08 | .14 | .51 |
| F/G | 1.07 | 1.02 | 1.12 | 1.08 | 1.10 | .03 | .20 | .02 | .58 | .98 |
| Day 0 to 14 | | | | | | | | | | |
| ADG, lb | .39 | .45 | .40 | .44 | .43 | .01 | .87 | .003 | .27 | .07 |
| ADFI, lb | .44 | .48 | .46 | .48 | .48 | .01 | .41 | .04 | .09 | .14 |
| F/G | 1.12 | 1.07 | 1.16 | 1.10 | 1.14 | .02 | .24 | .02 | .61 | .34 |
| Day 14 to 28 | | | | | | | | | | |
| ADG, lb | .77 | .75 | .71 | .78 | .77 | .03 | .11 | .71 | .56 | .57 |
| ADFI, lb | 1.08 | 1.08 | .98 | 1.07 | 1.08 | .04 | .04 | .27 | .51 | .88 |
| F/G | 1.42 | 1.44 | 1.40 | 1.39 | 1.41 | .03 | .65 | .49 | .79 | .42 |
| Day 0 to 28 | | | | | | | | | | |
| ADG, lb | .59 | .60 | .56 | .62 | .61 | .02 | .26 | .17 | .79 | .20 |
| ADFI, lb | .77 | .78 | .72 | .78 | .79 | .02 | .13 | .14 | .79 | .64 |
| F/G | 1.32 | 1.30 | 1.29 | 1.27 | 1.30 | .02 | .25 | .85 | .81 | .03 |

[a]A total of 305 weanling pigs (initially 9.0 lb and 12 to 13 d of age) with seven or eight pigs per pen and eight replications per treatment.

**Table 9. Effects of Replacing Spray-Dried Animal Plasma with High Molecular Weight, Whey Protein Concentrate when Fed from d 0 to 14 after Weaning on Pig Performance (Exp. 4)[a]**

| | Animal Plasma:Whey Protein Concentrate,% | | | | | | P < | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | 6.7:0 | 5.0:1.7 | 3.35:3.35 | 1.7:5.0 | 0:6.7 | SEM | Linear | Quad. | Cubic |
| Day 0 to 7 | | | | | | | | | |
| ADG, lb | .26 | .28 | .29 | .27 | .25 | .03 | .62 | .10 | .83 |
| ADFI, lb | .29 | .32 | .30 | .30 | .28 | .02 | .57 | .22 | .69 |
| F/G | 1.13 | 1.15 | 1.06 | 1.15 | 1.21 | .02 | .56 | .39 | .70 |
| Day 7 to 14 | | | | | | | | | |
| ADG, lb | .46 | .50 | .52 | .57 | .49 | .08 | .14 | .08 | .63 |
| ADFI, lb | .56 | .61 | .56 | .65 | .60 | .02 | .17 | .30 | .46 |
| F/G | 1.34 | 1.27 | 1.11 | 1.15 | 1.22 | .02 | .30 | .43 | .64 |
| Day 0 to 14 | | | | | | | | | |
| ADG, lb | .34 | .39 | .40 | .42 | .37 | .09 | .47 | .04 | .84 |
| ADFI, lb | .42 | .46 | .43 | .48 | .44 | .02 | .46 | .09 | .74 |
| F/G | 1.22 | 1.21 | 1.08 | 1.14 | 1.18 | .01 | .48 | .35 | .86 |
| Day 14 to 28 | | | | | | | | | |
| ADG, lb | .97 | 1.00 | .94 | 1.00 | 1.02 | .05 | .91 | .77 | .49 |
| ADFI, lb | .98 | 1.04 | .97 | 1.03 | 1.02 | .03 | .47 | .78 | .30 |
| F/G | 1.10 | 1.12 | 1.11 | 1.16 | 1.05 | .03 | .88 | .48 | .54 |
| Day 0 to 28 | | | | | | | | | |
| ADG, lb | .66 | .69 | .68 | .71 | .70 | .01 | .56 | .34 | .66 |
| ADFI, lb | .70 | .75 | .70 | .75 | .73 | .02 | .35 | .74 | .50 |
| F/G | 1.11 | 1.13 | 1.09 | 1.12 | 1.07 | .02 | .96 | .83 | .69 |

[a]A total of 320 weanling pigs (initially 9.2 lb and 12 to 13 d of age) with eight or nine pigs per pen and seven replications per treatment.

# EFFECTS OF SPRAY-DRIED EGG ALBUMIN ON GROWTH PERFORMANCE OF EARLY-WEANED PIGS

***M. De La Llata, R. D. Goodband, M. D. Tokach[1], J. L. Nelssen, S. S. Dritz[2], G. S. Grinstead, and J. C. Woodworth***

## Summary

Seventy two early-weaned pigs (initially 12.4 lb) were used in a 14-d growth trial to evaluate a control diet (no added spray-dried egg albumin or animal plasma) or the control diet with 5% spray-dried plasma, 7% spray-dried egg albumin, or 2.5% spray-dried plasma plus 3.5% spray-dried egg albumin. Pigs fed 5% spray-dried animal plasma had greater ADG and improved F/G compared with those fed 7% spray-dried egg albumin, whereas pigs fed the control or a blend of spray-dried egg albumin plus spray-dried animal plasma had intermediate performance. These results suggest that the spray-dried egg albumin used is not an effective replacement for spray-dried animal plasma in diets for early-weaned pigs.

(Key Words: Spray-Dried Egg, Early-Weaned Pigs, Performance.)

## Introduction

Swine nutritionist and producers are continually trying to reduce feed costs and improve overall profitability. One area often evaluated is the suitability of alternative protein sources to use in diets for early-weaned pigs. Currently, the protein source of choice is spray-dried animal plasma. Although this protein source is of high quality and improves growth performance of weaned pigs, it is very expensive. Therefore, finding a protein source that would offer a similar growth performance at a lower cost would greatly benefit the swine industry. Spray-dried whole egg protein has been shown to be an effective partial replacement for spray-dried animal plasma, but no information is available on the feeding value of spray-dried egg albumin. Therefore, the objective of this study was to evaluate the relative feeding values of spray-dried egg albumin and spray-dried animal plasma for early-weaned pigs.

## Procedures

Seventy-two (PIC L326 × C22, initially 12.3 lb and 19 days of age) early-weaned pigs were used in this experiment. Pigs were blocked by weight to one of four dietary treatments in a randomized complete block design. There were six pigs per pen and three pens per treatment. The dietary treatments (Table 1) consisted of a control diet (no added spray-dried egg albumin or animal plasma) or the control diet with 5% spray-dried animal plasma (replacing the lysine from soybean meal), 7% spray-dried egg albumin (also replacing soybean meal), or 2.5% spray-dried plasma plus 3.5% spray-dried egg albumin. Diets were fed in a meal form for the duration of the 14 d study.

Pigs were housed at the Kansas State University Swine Teaching and Research Center. Pigs were allowed ad libitum access to food and water through a dry feeder and one nipple waterer per pen.

Pigs were weighed and feed disappearance was determined weekly for the 14 d trial to calculate ADG, ADFI, and F/G. The spray-dried egg albumin was sampled and

[1]Northeast Area Extension Office, Manhattan, KS.
[2]Food Animal Health and Management Center.

analyzed for amino acids. The amino acid profile and that of spray-dried animal plasma are provided in Table 2.

## Results and Discussion

For the overall experiment (Table 3), ADG was greatest for pigs fed the 5% spray-dried animal plasma treatment and was greater (P<.05) than that of pigs fed 7% spray-dried egg albumin. Pigs fed the control and 3.5% spray-dried egg albumin plus 2.5% spray-dried animal plasma diets were intermediate. Average daily feed intake was not different (P>.05) among the dietary treatments. Feed efficiency was poorer (P<.05) for pigs fed the 7% spray-dried egg albumin diet than for pigs fed the rest of the dietary treatments. The best numerical responses for ADG, ADFI, and F/G were observed in pigs fed 5% spray-dried animal plasma.

The results from this experiment suggest that the spray-dried egg albumin used in this experiment is not suitable to replace spray-dried animal plasma in diets for weanling pigs.

**Table 1. Diet Composition**

| | Diet | | | |
|---|---|---|---|---|
| Item | Control | 5% Spray-dried animal plasma | 7% Spray-dried egg albumin | 3.5% Spray-dried egg albumin + 2.5% SDP |
| Corn | 45.88 | 49.72 | 47.73 | 48.73 |
| Soybean meal (46.5% CP) | 31.20 | 22.30 | 22.30 | 22.30 |
| Spray-dried animal plasma | – | 5.00 | -- | 2.5 |
| Spray-dried egg albumin | -- | -- | 7.00 | 3.50 |
| Dried whey | 15.00 | 15.00 | 15.00 | 15.00 |
| Soy oil | 3.00 | 3.00 | 3.00 | 3.00 |
| Monocalcium phosphate (21% P) | 1.70 | 1.60 | 1.90 | 1.80 |
| Limestone | .96 | 1.10 | .89 | .97 |
| Medication | 1.00 | 1.00 | 1.00 | 1.0 |
| Zinc oxide | .38 | .38 | .38 | .38 |
| Vitamin premix | .25 | .25 | .25 | .25 |
| Trace mineral premix | .15 | .15 | .15 | .15 |
| Salt | .25 | .25 | .25 | .25 |
| L-Lysine HCl | .15 | .15 | .15 | .15 |
| DL-Methionine | .08 | .10 | -- | .02 |
| | | | | |
| Lysine, % | 1.40 | 1.40 | 1.40 | 1.40 |
| Ca, % | .90 | .90 | .90 | .90 |
| P, % | .80 | .80 | .80 | .80 |

[a]Provided 50 g/ton carbodox.

**Table 2. Chemical Compositions of Spray-Dried Egg Albumin and Animal Plasma[a]**

| Item, % | Spray-Dried Egg Albumin | Spray-Dried Animal Plasma |
|---|---|---|
| Protein | 81.0 | 70.0 |
| Arginine | 4.6 | 5.3 |
| Cystine | 2.2 | 2.5 |
| Histidine | 1.9 | 2.8 |
| Isoleucine | 4.3 | 2.0 |
| Leucine | 7.0 | 5.6 |
| Lysine | 4.9 | 6.8 |
| Methionine | 2.8 | 0.5 |
| Phenylalanine | 5.0 | 4.1 |
| Threonine | 3.5 | 4.1 |
| Tryptophan | 1.5 | 1.3 |
| Tyrosine | 3.3 | 3.9 |
| Valine | 5.6 | 4.1 |

[a]Values expressed on an as-fed basis.

**Table 3. Effects of Spray-Dried Egg Albumin on Weanling Pig Performance[a]**

| | Treatment | | | | |
|---|---|---|---|---|---|
| Item | Control | 5% Spray-dried animal plasma | 7% Spray-dried egg albumin | 3.5% Spray-dried egg albumin + 2.5% SDP | CV |
| Day 0 to 14 | | | | | |
| ADG, lb | .63[bc] | .76[b] | .56[c] | .63[bc] | 14.7 |
| ADFI, lb | .85 | .96 | .90 | .86 | 10.9 |
| F/G | 1.4[b] | 1.26[b] | 1.63[c] | 1.37[b] | 6.5 |

[a]A total of 72 weanling pigs, initially 12.4 lb. Six pigs per pen and three pens per treatment.
[b,c]Means on the same row with different superscript differ (P<.05).

# EFFECTS OF FLASH-DRIED POULTRY PROTEIN AND SELECT MENHADEN FISH MEAL ON GROWTH PERFORMANCE OF WEANLING PIGS [1]

***S. A. Moser, M. D. Tokach [2], R. D. Goodband, J. L. Nelssen, J. C. Woodworth, and G. S. Grinstead***

## Summary

A total of 180 pigs (12.96 lb and 21 d of age) was used in a 28 d trial to determine the effects of substituting flash-dried poultry protein for select menhaden fish meal in the phase II diet on the performance of weanling pigs. Five dietary treatments were fed from d 7 to d 28 after weaning (phase II). Select menhaden fish meal (2.5 and 5%) and flash-dried poultry protein (2.85 and 5.7%) replaced soybean meal in the control diet on a lysine basis. Pigs fed the diets containing select menhaden fish meal and flash-dried poultry protein had similar ADG and ADFI; however, neither protein source improved performance when compared to the control diet. Further research must be conducted in a field environment in order to determine if fish meal and poultry protein will express a greater response compared to the control diet.

(Key Words: Poultry Protein, Fish Meal.)

## Introduction

The development of a complex nursery diet with highly digestible nutrients has created a demand for specialty proteins such as select menhaden fish meal. However, recent weather events (El Nino) have been blamed for a decrease in the menhaden fish catch and a reduced supply of high quality fish meal for the feed industry. Flash-dried poultry protein is high in protein with an amino acid profile comparable to that of select menhaden fish meal (Table 1). The objective of this experiment was to compare flash-dried poultry protein to select menhaden fish meal in phase II nursery diets.

## Procedures

A total of 180 pigs (initially 12.96 lb and 21 d of age) was used in a 28-day growth trial. Pigs were blocked by weight, equalized for gender and ancestry, and allotted randomly to one of five dietary treatments with a total of six pigs per pen and six pens per treatment. Pigs were housed in an environmentally controlled nursery in $5 \times 5$ ft pens with one self-feeder and nipple waterer to allow ad libitum access to feed and water. Pigs were weighed and feed disappearance was determined on d 0, 7, 14, 21 and 28 to calculate ADG, ADFI, and F/G.

**Table 1. Compositions of Flash-Dried Poultry Protein and Menhaden Fish Meal [a]**

| Item, % | Poultry Protein | Fish Meal |
|---|---|---|
| Protein | 65.0 | 61.2 |
| Calcium | 3.10 | 5.19 |
| Phosphorus | 3.00 | 2.88 |
| Lysine | 4.17 | 4.74 |
| Isoleucine | 2.61 | 2.85 |
| Leucine | 4.80 | 4.48 |
| Methionine | 0.84 | 1.75 |
| Met. & Cys. | 1.45 | 2.33 |
| Threonine | 3.00 | 2.51 |
| Tryptophan | 0.53 | 0.65 |
| Valine | 3.25 | 3.19 |

[a]Values expressed on an as-fed basis.

[1]The authors thank Griffin Industries for providing the flash-dried poultry protein and partial financial support.

[2]Northeast Area Extension Office, Manhattan, KS.

The trial had two phases with experimental diets being fed from d 7 to 28. The phase I diet was a pelleted corn-soybean based diet containing 5% spray-dried animal plasma, 1.65% spray dried blood meal, 2.5% select menhaden fish meal, and 20% dried whey (Table 2). This diet was fed to all pigs from d 0 to d 7 and was formulated to contain 1.5% lysine, .42% methionine, .9% Ca, and .8% P. The phase II diets consisted of a control, two levels of select menhaden fish meal (2.5 and 5%), and two levels of flash-dried poultry protein (2.85 and 5.7%). The fish meal and poultry protein replaced soybean meal on a lysine basis. All phase II diets contained 10% dried whey and were formulated to contain 1.25% lysine.

Data were analyzed as a randomized complete block design using general linear model procedures. Initial weight was used to establish blocks. Pig weight on d 7 was used as a covariate for the phase II analysis, and the data were tested for linear and quadratic responses within each protein source.

## Results and Discussion

No differences were observed in ADG, ADFI, and F/G when pigs were fed a common phase I diet (d 0 to 7 postweaning). From d 7 to 28 (phase II), ADG and ADFI were similar among pigs fed the fish meal and poultry protein diets (Table 3). However, the pigs on the control diet had higher ADG ($P<.05$) and ADFI ($P<.05$). Increasing levels of both fish meal and poultry protein in phase II diets resulted in linear reductions ($P<.05$) in ADG and ADFI. Feed efficiency was similar across all treatments.

For the cumulative study (d 0 to 28), ADG and F/G were not influenced by protein source. However, increasing fish meal in the diet linearly reduced ($P<.05$) ADFI.

These results suggest that little difference in growth performance occurs between pigs fed select menhaden fish meal and flash-dried poultry protein. In addition, pigs fed the control diet tended to have higher ADG and ADFI, suggesting that the use of dried whey with no other specialty proteins provided adequate growth for pigs in this particular research environment. This situation demands further research in a field study to determine if nursery pigs fed the previously discussed phase II diets will respond in a similar manner or not.

**Table 2. Experimental Diets**

| | | | Select Menhaden Fish Meal | | Flash-Dried Poultry Protein | |
|---|---|---|---|---|---|---|
| Ingredient, % | Phase I | Control | 2.50% | 5.00% | 2.85% | 5.70% |
| Corn | 45.75 | 52.93 | 55.21 | 57.50 | 54.68 | 56.40 |
| Soybean meal, 46.5% | 15.78 | 29.13 | 24.82 | 20.49 | 24.83 | 20.50 |
| Choice white grease | | 3 | 3 | 3 | 3 | 3 |
| Monocalcium phos., 21% P | 1.28 | 1.85 | 1.60 | 1.35 | 1.70 | 1.55 |
| Limestone | .79 | 1 | .80 | .60 | .85 | .75 |
| Salt | .1 | .25 | .25 | .25 | .25 | .25 |
| Vitamin premix | .25 | .25 | .25 | .25 | .25 | .25 |
| Trace mineral premix | .15 | .15 | .15 | .15 | .15 | .15 |
| Antibiotic | 1 | 1 | 1 | 1 | 1 | 1 |
| Zinc oxide | .38 | .25 | .25 | .25 | .25 | .25 |
| Lysine HCl | .15 | .15 | .15 | .15 | .15 | .15 |
| DL-methionine | .125 | .045 | .025 | .01 | .045 | .05 |
| Select menhaden fishmeal | 2.5 | | 2.5 | 5 | | |
| Flash-dried poultry protein | | | | | 2.85 | 5.7 |
| Spray dried whey | 20 | 10 | 10 | 10 | 10 | 10 |
| Spray-dried animal plasma | 5 | | | | | |
| Spray-dried blood meal | 1.75 | | | | | |
| Soybean oil | 5 | | | | | |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Calculated analysis, % | | | | | | |
| Lysine | 1.5 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 |
| Crude protein | 21.14 | 19.4 | 19.1 | 18.8 | 19.4 | 19.4 |
| Ca | 0.90 | 0.90 | 0.90 | 0.89 | 0.89 | 0.90 |
| P | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 |

**Table 3. Evaluation of Flash-Dried Poultry Protein and Select Menhaden Fish Meal in Phase II Diets [a]**

| | | Fish Meal, % | | Poultry Protein, % | | |
|---|---|---|---|---|---|---|
| Item | Control | 2.5 | 5.0 | 2.85 | 5.7 | CV |
| Day 0 to7 | | | | | | |
| ADG | .71 | .72 | .75 | .73 | .75 | 9.18 |
| ADFI | .71 | .70 | .78 | .70 | .71 | 8.43 |
| F/G | 1.01 | .98 | 1.04 | .96 | .96 | 9.91 |
| Day 7 to 28 [b] | | | | | | |
| ADG[e,f] | 1.09[c] | 1.03[d] | .98[d] | 1.01[d] | 1.00[d] | 4.98 |
| ADFI[e,f] | 1.78 [c] | 1.74 [c,d] | 1.64 [d] | 1.67 [d] | 1.65 [d] | 5.17 |
| F/G | 1.64 | 1.69 | 1.66 | 1.64 | 1.63 | 5.46 |
| Day 0 to 28 | | | | | | |
| ADG | .99 | .95 | .94 | .93 | .95 | 6.53 |
| ADFI[e] | 1.51 | 1.47 | 1.43 | 1.42 | 1.42 | 5.47 |
| F/G | 1.53 | 1.57 | 1.53 | 1.52 | 1.50 | 5.42 |

[a]A total of 180 weanling pigs, initially 12.96 lb and 21 days of age, with six pigs per pen and six pens per treatment.
[b]d 7 weight was used as a covariate.
[c,d] Means on the same row within control or protein source with different superscripts differ (P<.05).
[e]Linear effect for select menhaden fish meal (P<.05).
[f]Linear effect for flash-dried poultry protein (P<.05).

# EVALUATION OF A PORCINE COPRODUCT (PRO-BLEND 75®) FROM SLAUGHTER PLANTS AS A PROTEIN SOURCE FOR STARTER PIG DIETS [1]

***D. J. Lee, B. R. Dunsford [2], J. D. Hancock, K. L. Herkelman [2], M. D. Tokach [3], J. D. Hahn [2]***

## Summary

Pellet durability index was greatest when animal protein products (dried whey, fish meal, spray-dried blood cells, and a porcine coproduct) were used in place of soybean meal. However, no differences occurred in ADG, ADFI, or F/G among segregated early-weaned piglets (10.1 lb) fed the various protein sources.

(Key Words: Animal Protein, Soybean Meal, Nursery Pigs.)

## Introduction

Diets with high quality protein sources are important parts of maximized growth performance in weanling pigs. Farmland Industries has developed a blended protein source (Pro-Blend 75®) composed of red blood cells, hydrolyzed tissues, and other highly digestible proteins from their porcine slaughter facilities. The objective of the experiment reported herein was to compare this new coproduct with other commonly used protein sources (e.g., dried whey, select menhaden fish meal, and spray-dried blood cells) in diets for weanling pigs.

## Procedures

A total of 150 (average initial weight of 10.1 lb) weanling pigs (PIC 327 x C22) was blocked by weight and sex and assigned to pens. There were six pigs/pen and five pens/treatment. Treatments were: 1) corn-soybean meal-based control; 2) dried whey; 3) fish meal; 4) blood cells; and 5) porcine coproduct. The animal protein sources were substituted for soybean meal on a lysine basis (Table 1) and fed for d 0 to 14 of the 28-d growth assay. Total dietary lysine was 1.30 % (i.e., deficient) and the formulations were simple, thus accentuating the effects of differences among the protein sources. All diets had 14.4% lactose and 3% choice white grease. A corn-soybean meal-based diet (formulated to 1.25 % lysine) was fed from d 14 to 28 to see if the Phase I protein sources had carryover effects on growth performance to the end of the nursery period.

The pigs were housed in an environmentally controlled nursery facility. Room temperature was initially 90°F, and the temperature was decreased by .4°F each day thereafter. The pens were 3 ft × 6 ft and equipped with woven wire floors. Each pen had a four-hole self-feeder and a nipple waterer to allow ad libitum intake of feed and water.

The diets were pelleted at 143°F using a 1in.-thick die with 1/8 in.-diameter holes. The diets were conditioned for 10 seconds prior to pelleting and cooled after pelleting in a counter-flow cooler. One-pound samples of the pellets were collected and subsampled to determine pellet durability index (PDI). For the PDI determination, a tumbling box pellet tester was used. Briefly, 500 grams of the screened pellets were weighed into each

[1]Appreciation is extended to the Farmland Research and Development Farm for use of facilities and pigs.

[2]Farmland Industries, Inc.

[3]Northeast Area Extension Office, Manhattan, KS.

of the four compartments of the pellet tester. In two of the boxes, five hexagonal nuts (1/2 in.) were added to further distress the pellets. The box was tumbled for 10 min and the percentage of the original pellets that would not pass through a No. 8 sieve was used as the expression for pellet durability.

All growth data were analyzed as a randomized complete block design with pen as the experimental unit. Orthogonal contrasts were used to separate treatment means. Response criteria were ADG, ADFI, and F/G.

## Results and Discussion

Concentrations of amino acids (Table 2) in the soybean meal, whey, fish meal, and blood cells were similar to values published in the NRC (1998). Also, the analyzed values for the porcine coproduct were similar to the values published by Farmland Industries.

Pellet durability index was improved ($P<.001$) when animal protein products were added to the diet (Table 3). Among the animal protein products, the ranking (from best to worst) for pellet durability index was whey > porcine coproduct > blood cells > fish meal ($P<.001$).

For d 0 to 14, 14 to 29, and overall (d 0 to 29), no differences ($P>.15$) were observed in ADG, ADFI or F/G among pigs fed the various protein sources. However, numerical advantages occurred when animal protein products were used to replace soybean meal. The lack of significant response to animal protein products likely resulted from the very small initial weight of the pigs used in this experiment. An average initial weight of 12 lb was anticipated; however, upon arrival the segregated early-weaned piglets had an average initial weight of only 10.1 lb. Thus, the extremely simple formulations and low lysine concentrations in the diets severely restricted growth performance and may have prevented expression of the superior performance generally associated with use of animal products.

**Table 1. Diet Composition[a]**

| | Treatments[b] | | | | | |
|---|---|---|---|---|---|---|
| Item | Soybean meal | Whey | Fish meal | Blood cells | Porcine coproduct | Phase II |
| Ingredient, % | | | | | | |
| Corn | 43.53 | 45.00 | 46.96 | 47.83 | 47.79 | 61.28 |
| Soybean meal | 34.65 | 28.18 | 28.18 | 28.19 | 28.19 | 32.16 |
| Whey | - | 20.00 | - | - | - | - |
| Fish meal | - | - | 3.69 | - | - | - |
| Blood cells | - | - | - | 2.07 | - | - |
| Porcine coproduct | - | - | - | - | 3.06 | - |
| Lactose[c] | 14.40 | - | 14.40 | 14.40 | 14.40 | - |
| Choice white grease | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Monocalcium phosphate | 1.95 | 1.45 | 1.55 | 2.05 | 2.05 | 1.55 |
| Limestone | 1.00 | .90 | .75 | .95 | 1.00 | .95 |
| Salt | .35 | .35 | .35 | .35 | .35 | .35 |
| Vitamin premix | .25 | .25 | .25 | .25 | .25 | .25 |
| Trace mineral premix | .15 | .15 | .15 | .15 | .15 | .15 |
| Zinc oxide | .25 | .25 | .25 | .25 | .25 | - |
| Lysine HCl | .15 | .15 | .15 | .15 | .15 | .15 |
| DL-methionine | .07 | .07 | .07 | .11 | .11 | .03 |
| Antibiotic[d] | .25 | .25 | .25 | .25 | .25 | .13 |
| Calculated lysine, % | 1.30 | 1.30 | 1.30 | 1.30 | 1.30 | 1.25 |
| Analyzed lysine, % | 1.28 | 1.26 | 1.27 | 1.27 | 1.29 | 1.26 |

[a]Calcium and P were .85% and .75% in phase I and .75% and .70% in Phase II.

[b]Dehulled soybean meal was supplied by Archer Daniels Midland Company, Kansas City, MO; edible dried whey was supplied by Beatrice Cheese, Inc., Waukasha, WI; Select Menhaden Fish Meal was supplied by Zapata Protein USA, Mandeville, LA; blood cells (AP 301) were supplied by American Protein Corporation, Manning, IA; porcine coproduct (Pro-Blend 75®) were supplied by Farmland Industries, Inc., Kansas City, MO.

[c]International Ingredient Corporation, St. Louis, MO.

[d]Provided 50 g/ton carbadox.

**Table 2. Amino Acid Compositions of the Protein Sources (As-Fed Basis)[a]**

| Amino Acid | Soybean Meal | Whey | Fish Meal | Blood Cells | Porcine Coproduct |
|---|---|---|---|---|---|
| Essential | | | | | |
| Arginine | 3.39 | .24 | 3.73 | 3.69 | 4.01 |
| Histidine | 1.28 | .19 | 1.52 | 7.02 | 3.01 |
| Isoleucine | 2.15 | .59 | 2.44 | .39 | 1.79 |
| Leucine | 3.69 | 1.02 | 4.27 | 12.21 | 6.63 |
| Lysine | 2.96 | .84 | 4.73 | 7.95 | 6.15 |
| Methionine | .68 | .14 | 1.65 | .69 | .84 |
| Phenylalanine | 2.43 | .33 | 2.36 | 6.25 | 3.44 |
| Threonine | 1.86 | .62 | 2.44 | 2.75 | 2.49 |
| Tryptophan | .70 | .16 | .64 | 1.53 | .38 |
| Valine | 2.26 | .56 | 2.94 | 8.37 | 4.59 |
| Nonessential | | | | | |
| Alanine | 2.05 | .48 | 3.77 | 7.29 | 5.32 |
| Aspartic acid | 5.29 | 1.01 | 5.31 | 10.32 | 6.67 |
| Cysteine | .74 | .23 | .55 | .71 | .71 |
| Glutamic acid | 8.51 | 1.70 | 7.40 | 7.10 | 8.35 |
| Glycine | 1.96 | .21 | 4.23 | 4.25 | 6.61 |
| Hydroxyproline | .05 | .00 | .81 | .00 | 1.87 |
| Proline | 2.38 | .58 | 2.72 | 3.24 | 4.60 |
| Serine | 2.18 | .42 | 1.97 | 3.24 | 2.73 |
| Taurine | .03 | .09 | .59 | .03 | .19 |
| Tyrosine | 1.73 | .29 | 1.89 | 1.98 | 1.87 |

[a]Dehulled soybean meal was supplied by Archer Daniels Midland Company, Kansas City, MO; edible dried whey was supplied by Beatrice Cheese, Inc., Waukasha, WI; Select Menhaden Fish Meal was supplied by Zapata Protein USA, Mandeville, LA; blood cells (AP 301) were supplied by American Protein Corporation, Manning, IA; porcine coproduct (Pro-Blend 75®) were supplied by Farmland Industries, Inc., Kansas City, MO.

**Table 3. Growth Performance of Weanling Pigs Fed Starter Diets with Various Protein Sources[a]**

| | Treatments | | | | | | Contrast, P < [b] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | Soybean meal | Whey | Fish meal | Blood cells | Porcine coproduct | SE | 1 | 2 | 3 | 4 |
| Pellet durability index, %[c] | | | | | | | | | | |
| w/o nuts | 78.3 | 98.3 | 73.7 | 85.0 | 91.0 | .31 | .001 | .001 | .001 | .001 |
| w/nuts | 55.2 | 96.2 | 49.4 | 65.2 | 81.0 | 1.09 | .001 | .001 | .001 | .001 |
| Phase I (d 0 to 14) | | | | | | | | | | |
| ADG, lb | .31 | .34 | .30 | .32 | .29 | .21 | -[e] | - | - | - |
| ADFI, lb | .47 | .48 | .46 | .46 | .44 | .02 | - | - | - | - |
| F/G | 1.55 | 1.44 | 1.54 | 1.42 | 1.51 | .06 | - | - | - | - |
| Phase II (d 14 to 29)[d] | | | | | | | | | | |
| ADG, lb | .75 | .83 | .79 | .81 | .79 | .04 | - | - | - | - |
| ADFI, lb | 1.13 | 1.17 | 1.19 | 1.19 | 1.15 | .04 | - | - | - | - |
| F/G | 1.50 | 1.42 | 1.51 | 1.46 | 1.46 | .05 | - | - | - | - |
| Overall (d 0 to 29) | | | | | | | | | | |
| ADG, lb | .54 | .59 | .55 | .58 | .55 | .02 | - | - | - | - |
| ADFI, lb | .81 | .84 | .84 | .83 | .80 | .03 | - | - | - | - |
| F/G | 1.52 | 1.43 | 1.52 | 1.45 | 1.47 | .04 | - | - | - | - |

[a]A total of 150 barrows and gilts (avg initial wt of 10.1 lb) were allotted with six pigs/pen and five pens/trt.
[b]Contrasts were: 1) SBM vs others; 2) whey vs others; 3) fish meal vs blood products; and 4) blood cells vs porcine coproduct.
[c]Pellet durability index was determined with 500 g samples of screened pellets placed in tumbling boxes with or without 5 hexagonal nuts.
[d]The Phase II diet was fed to all pigs for d 14 to 29.
[e]Dashes indicate P>.15.

# APPARENT ILEAL DIGESTIBLITY OF AMINO ACIDS AND DIGESTIBLE AND METABOLIZABLE ENERGY VALUES FOR CONVENTIONAL SOYBEAN MEAL OR DRY EXTRUDED-EXPELLED SOYBEAN MEAL FOR SWINE [1]

*J. C. Woodworth, M. D. Tokach [2], R. D. Goodband, J. L. Nelssen, P. R. O'Quinn, and D. A. Knabe [3]*

## Summary

We conducted two experiments to determine the apparent ileal digestibility of amino acids and digestible energy (DE) and metabolizable energy (ME) values for conventionally processed, solvent-extracted soybean meal (SBM) compared to dry-extruded-expelled SBM with or without soy hulls. Apparent ileal digestibility of crude protein and lysine and DE and ME values were greater in either extruded-expelled SBM compared to the conventionally processed SBM. No differences occurred in apparent digestibility of amino acids or energy values between extruded-expelled SBM with hulls and that without hulls. These results suggest that the dry extrusion followed by expeller processing of soybeans results in a SBM with slightly greater digestibility of crude protein and lysine as well as greater DE and ME values compared to conventionally processed, solvent-extracted SBM.

(Key Words: Soybean Meal, Processing, Digestibility, Energy.)

## Introduction

Extrusion processing is an effective means of improving the nutritional value of whole soybeans fed to swine. A relatively recent advancement has been the use of an expeller to remove the oil from the soybeans. This results in an extruded-expelled soybean meal (SBM) that contains slightly higher levels of fat than solvent-extracted SBM. This extruded-expelled SBM has potential advantages in swine diets because of the increased energy content and decreased dustiness from the higher fat levels.

Therefore, the objectives of these experiments were to determine the apparent ileal amino acid digestibility and DE and ME values of SBM produced by dry extrusion followed by expelling and compare these values with those of conventionally processed, solvent-extracted SBM.

## Procedures

The Kansas State University Institutional Animal Care and Use Committee approved protocols used in this experiment. Two experiments were conducted to determine the apparent ileal digestibility of amino acids and DE and ME values for dry-extruded-expelled SBM with and without hulls and conventionally processed, solvent extracted SBM. Extruded-expelled SBM products were processed by the Insta-Pro Express™ extruder/press system, using the Model 2500 Insta-Pro Dry-Extruder and Model 1500 Continuous Horizontal Press. Extruder temperatures and production rates for extruded-expelled SBMs with and without hulls were 312 and 316ºF and 1,875 and 1925 lb/hr, respectively.

---

[1]The authors thank Insta-Pro International, a division of Triple "F", Des Moines, IA for partially funding this trial and for supplying extruded, expelled soybean meal. The authors also thank Edward J. Gregg for laboratory assistance.

[2]Northeast Area Extension Office, Manhattan, KS.

[3]Department of Animal Science, Texas A & M University, College Station, TX.

In Exp. 1, six barrows (initially 85 lb) were fitted surgically with a simple T-cannula approximately 15 cm anterior to the ileocecal valve. Pigs were used previously to determine the digestibility of amino acids in different corn varieties but were allowed 15 days of adjustment before the start of this experiment. Pigs were housed in stainless-steel metabolism cages and randomly allotted to one of three dietary treatments in a replicated 3 × 3 Latin square design. Diets were formulated to .80% total lysine using analyzed nutrient compositions of the three SBM sources (Table 1). The diets used in Exp. 1 were cornstarch based and contained either commercially obtained solvent-extracted SBM, extruded-expelled SBM with hulls, or extruded-expelled SBM without hulls (Table 2). All diets were formulated so that each SMB source provided the same amount of total lysine. All diets contained .25% chromic oxide as an indigestible marker.

Each 5-d feeding period consisted of a 3-d acclimation period followed by collection of ileal digesta for 2 days (8 h/d). Feed was divided into two equal meals and fed at 0600 and 1800 each day. All pigs were fed 3.0, 3.2, and 3.4 lb/d during periods 1, 2, and 3, respectively. Daily feed was determined by maintaining intakes of 3.0 to 3.5% of BW. Water was provided twice daily at a rate of 2:1 water:feed (wt:wt). Average weight of the pigs at the end of period 3 was 105 lb.

Ileal digesta was collected between 0600 and 1400 on 2 consecutive days by attaching a latex balloon to the cannula. Digesta in the balloon was collected periodically and stored on ice during the 8-h collection period. At the end of each day's collection, a .5 lb subsample was taken and frozen. The two subsamples from each pig in their respective period were homogenized, freeze-dried, and ground before analysis. All nutrient digestibilities were calculated using chromic oxide as the indigestible marker.

In Exp. 2, six barrows (initially 91 lb) were used to determine DE and ME values for the three SMB sources. Pigs were housed in stainless-steel metabolism cages designed to allow separate collection of urine and feces. Pigs were allotted to one of three experimental treatments in a replicated 3 × 3 Latin square design. The three SBM sources used were from the same batches as those used in Exp.1. Diets (Table 3) were formulated to contain 25% of one of three different SBM sources. Because the corn in each diet also supplied dietary energy, a fourth diet containing all ingredients except SBM was fed at the end of the experiment. The fourth collection period was used to determine the energy value of the corn, so energy values for the SBM could be determined by difference.

The four feeding periods consisted of 3 days of diet acclimation followed by 4 days of total fecal and urine collection. Feces were collected twice daily and pooled for each period. The feces then were mixed, and a representative subsample was freeze-dried and ground for chemical analysis. Ferric oxide (1% of diet) was used as the indigestible marker to identify the beginning and end of each collection period. Urine was collected into plastic bottles containing 25 mL of 6 *N* HCl. Ten percent of each day's output (volume basis) was stored frozen, pooled within a collection period, centrifuged to remove trace amounts of particulate matter, and then analyzed.

Feed was divided into two equal meals and fed at 0600 and 1800 each day. Daily feed intakes were 2.7, 3.2, 3.6, and 4.0 lb/d for periods 1, 2, 3, and 4, respectively, maintaining intakes of 3% of BW. Water was provided twice daily at a rate of 2:1 water:feed (wt:wt). Average weight of the pigs at the end of period 4 was 134 lb.

Data were analyzed using the GLM procedure of SAS with pig as the experimental unit. Data from both trials were analyzed as a replicated 3 × 3 Latin square design in which the model included the effects of treatment, square (replication), period, and 2-way interactions of pig and square.

## Results and Discussion

Analyzed nutrient compositions of the three SBM sources suggest that many nutrients are higher in the extruded-expelled sources compared to the conventionally processed SBM (Table 1). However, the extruded-expelled SMB sources were 6 to 7 percentage units higher in DM than the conventionally processed SBM. When the SBM sources are compared on an equal DM basis, their nutrient profiles are very similar.

No differences (P>.14) in apparent ileal digestibility of nutrients occurred among the two extruded-expelled SBMs (Table 4). However, the apparent ileal digestibilities of crude protein (CP), lysine, valine, isoleucine, and some other amino acids were greater (P<.05) for the extruded-expelled products compared to the conventionally processed, solvent-extracted SBM. Digestibility values for the conventionally processed SBM are similar to published data (NRC, 1998).

Energy values for the three SBM products showed the same trend as CP and amino acid digestibility values (Table 5). No differences (P>.13) in DE or ME occurred between the two extruded-expelled SBM products. However, the conventionally processed SBM had lower (P<.0001) DE and ME compared to either extruded-expelled product. The DE and ME for the conventionally processed SBM product were similar to published values (1.67 and 1.53 Mcal/lb; respectively) (NRC, 1998).

In conclusion, nutrient composition of extruded-expelled SBM with and without hulls is similar to that of conventionally processed SBM on an equal DM basis. The apparent ileal digestibilities of some nutrients (CP and lysine) are increased with the extrusion, expeller technology compared to solvent-extraction. Thus, the waste should have lower nutrient concentrations when extruded-expelled SBM products are used. The extruded-expelled products also have higher energy values than the conventionally processed SBM.

**Table 1. Analyzed Nutrient Composition of Soybean Meal Sources[a]**

| | | Dry Extruded-Expelled | |
|---|---|---|---|
| Item | Solvent-Extracted | With hulls | Without hulls |
| DM, % | 88.25 | 94.59 | 95.96 |
| CP, % | 47.14 | 47.52 | 50.47 |
| GE, Mcal/lb | 1.93 | 2.12 | 2.14 |
| Ash, % | 6.76 | 6.03 | 6.24 |
| Fat, % | 1.14 | 4.89 | 5.86 |
| Fiber, % | 3.60 | 4.80 | 3.30 |
| Urease activity, Δ pH | .03 | .03 | .03 |
| Free fatty acid, % | 9.1 | 1.7 | .90 |
| Peroxide value, meq/kg | 21 | 33 | 40 |
| Amino acids, %: | | | |
| Arginine | 3.37 | 3.85 | 3.57 |
| Histidine | 1.27 | 1.27 | 1.35 |
| Isoleucine | 2.14 | 2.08 | 2.31 |
| Leucine | 3.66 | 3.68 | 3.89 |
| Lysine | 2.97 | 2.96 | 3.11 |
| Methionine | .66 | .65 | .69 |
| Phenylalanine | 2.41 | 2.41 | 2.58 |
| Threonine | 1.83 | 1.85 | 1.93 |
| Tryptophan | .68 | .73 | .72 |
| Valine | 2.30 | 2.24 | 2.46 |
| Alanine | 2.12 | 2.10 | 2.21 |
| Aspartic acid | 5.29 | 5.28 | 5.59 |
| Cysteine | .73 | .82 | .83 |
| Glutamic acid | 8.30 | 8.19 | 8.72 |
| Glycine | 1.99 | 1.99 | 2.07 |
| Proline | 2.35 | 2.32 | 2.44 |
| Serine | 2.10 | 2.16 | 2.19 |
| Tyrosine | 1.69 | 1.69 | 1.78 |

[a]Values expressed on an as-fed basis.

**Table 2. Diet Composition, Exp. 1[a]**

| | | Dry Extruded-Expelled | |
|---|---|---|---|
| Ingredient, % | Solvent-Extracted | With hulls | Without hulls |
| Corn starch | 68.57 | 69.01 | 70.13 |
| Soybean meal, 46.5% | 27.47 | - | - |
| Extruded-expelled SBM | | | |
| with hulls | - | 27.03 | - |
| without hulls | - | - | 25.91 |
| Monocalcium phosphate | 2.29 | 2.29 | 2.29 |
| Limestone | .67 | .67 | .67 |
| Salt | .35 | .35 | .35 |
| Vitamin premix | .25 | .25 | .25 |
| Trace mineral premix | .15 | .15 | .15 |
| Chromic oxide | .25 | .25 | .25 |
| | | | |
| Calculated analysis, % | | | |
| CP | 12.65 | 12.43 | 12.60 |
| Lysine | .80 | .80 | .80 |
| Ca | .75 | .75 | .75 |
| P | .66 | .65 | .65 |

[a]Values expressed on an as-fed basis.

**Table 3. Diet Composition, Exp. 2[a]**

| Item, % | Periods 1, 2, and 3 | Period 4[b] |
|---|---|---|
| Corn | 71.59 | 96.22 |
| Soybean meal[c] | 25.00 | - |
| Monocalcium phosphate | 1.39 | 1.81 |
| Limestone | 1.07 | 1.02 |
| Salt | .35 | .35 |
| Chromic oxide | .25 | .25 |
| Vitamin premix | .20 | .20 |
| Trace mineral premix | .15 | .15 |

[a]Values expressed on an as-fed basis.
[b]The corn diet was used to determine the energy value of corn, so energy values of the soybean meal products could be determined by difference.
[c]The source of soybean meal, conventionally processed 46.5% CP soybean meal or extruded-expelled soybean meal with hull or without hulls, to provide three experimental treatments.

**Table 4. Apparent Ileal Digestibility (%) of Nutrients in Soybean Meal[a]**

| | Soybean Meal Processing Technique | | | |
|---|---|---|---|---|
| | | Dry Extruded-Expelled | | |
| Item | Solvent-extracted | With hulls | Without hulls | SEM |
| DM | 84.79 | 85.67 | 85.84 | .58 |
| CP | 83.22[b] | 86.21[c] | 85.42[c] | .82 |
| Ash | 37.29 | 36.53 | 33.30 | 1.73 |
| Amino Acids | | | | |
| Arginine | 91.39[b] | 93.70[c] | 93.75[c] | .21 |
| Histidine | 88.07 | 89.42 | 89.91 | .59 |
| Isoleucine | 86.95[b] | 89.72[c] | 89.85[c] | .37 |
| Leucine | 85.52[b] | 88.48[c] | 88.58[c] | .47 |
| Lysine | 88.58[b] | 90.90[c] | 91.08[c] | .51 |
| Methionine | 89.10 | 88.85 | 88.51 | .50 |
| Phenylalanine | 86.80[b] | 90.01[c] | 90.40[c] | .38 |
| Threonine | 78.15 | 79.14 | 79.79 | .96 |
| Tryptophan | 86.96 | 88.38 | 87.25 | .61 |
| Valine | 85.23[b] | 87.37[c] | 87.42[c] | .51 |
| Alanine | 82.34[b] | 85.05[c] | 85.40[c] | .83 |
| Aspartic acid | 85.72[b] | 88.93[c] | 89.22[c] | .51 |
| Cysteine | 80.72 | 81.98 | 82.65 | .95 |
| Glutamic acid | 89.85[b] | 92.51[c] | 92.57[c] | .33 |
| Glycine | 75.19 | 73.35 | 76.54 | 1.53 |
| Proline | 83.23 | 81.60 | 83.29 | 1.72 |
| Serine | 82.65[b] | 84.66[c] | 84.94[c] | .57 |
| Tyrosine | 84.67 | 86.91 | 86.65 | .72 |

[a]Values are the means of six pigs (initially 85 lb) used in a replicated 3 × 3 Latin square design.
[b,c]Means within a row with different superscripts differ (P<.05).

**Table 5. Energy Values of Soybean Meal Sources, Mcal/lb[a]**

| | Soybean Meal Processing Technique | | |
|---|---|---|---|
| | | Dry Extruded-Expelled | |
| Item | Solvent-extracted | With hulls | Without hulls |
| Digestible energy | 1.66[b] | 1.87[c] | 1.91[c] |
| Metabolizable energy | 1.55[b] | 1.76[c] | 1.80[c] |

[a]Values are the means of six pigs (initially 91 lb) used in a replicated 3 × 3 Latin square design.
[b,c]Means within a row with different superscripts differ (P<.05).

# EFFECTS OF DIFFERENT SOYBEAN MEAL PROCESSING TECHNIQUES ON GROWTH PERFORMANCE OF PIGS [1]

***J. C. Woodworth, M. D. Tokach [2], J. L. Nelssen, R. D. Goodband, and R. E. Musser***

## Summary

A 35-d growth trial was conducted to determine the influence of different soybean meal processing techniques on starter pig growth performance. From d 0 to 14 after weaning, all pigs were fed a common diet. Then pigs were fed six experimental diets from d 14 to 35 after weaning. Three treatment comparisons were made. Pigs fed a diet containing extruded-expelled soybean meal (SBM) without hulls (Insta-Pro) were compared to those fed solvent-extracted SBM (46.5% CP) and 3.21% soy oil. Pigs fed a diet containing extruded-expelled SBM with hulls (Insta-Pro) were compared to those fed a diet containing 44% CP SBM and 4.57% soy oil. Pigs fed a diet containing a second expelled SBM product with hulls (Soyplus) were compared to those fed a diet containing 44% CP SBM and 1.61% soy oil. Pigs fed either Insta-Pro extruded-expelled diet had similar growth performance to pigs fed diets containing conventionally processed soybean meal and added oil. Pigs fed diets containing Soyplus had numerically lower ADG and higher F/G than pigs fed any other treatment. These data suggest that Insta-Pro extruded-expelled SBM can replace conventionally processed SBM and added soy oil on a lysine and energy basis without affecting growth performance.

(Key Words: Soybean Meal, Processing, Growth, Starter Pigs.)

## Introduction

Extrusion processing has been shown to improve the feeding value of whole soybeans and soybean meal (SBM). The technology of extrusion followed by expelling has led to the development of an SBM product that has a higher fat content than solvent-extracted SBM (approximately 5 vs 1%, respectively). In previous experiments (pg. 49), apparent ileal digestibility of amino acids and DE and ME values were determined for two different dry-extruded-expelled SBM products produced by the Insta-Pro Express™ extruder/press system. Soyplus is another commercially available expelled SBM product. Relatively little information is available on the influence of Soyplus on pig performance. Therefore, the objective of this experiment was to compare the growth performance of pigs fed diets containing extruded-expelled SBM and those fed solvent-extracted SBM formulated to the same digestible lysine and ME concentrations.

## Procedures

A total of 216 weanling pigs (initially 13.4 lb and 21 d of age) was used in a 35-d growth trial. Pigs (PIC L-326 × C-22) were weaned into pens and fed 1 lb of a segregated early-wean diet (1.6% lysine) per pig (Table 1). A transition diet (1.45% lysine) was fed for the remainder of the 14 d period (Table 1). On d 12, pigs were weighed and randomly allotted by sex, ancestry, and

[1]The authors thank Insta-Pro International, a division of Triple "F", Des Moines, IA for partially funding this trial and for supplying the extruded, expelled soybean meals used.

[2]Northeast Area Extension Office, Manhattan, KS.

weight into six replications of six pens. Each pen contained six pigs. On d 14, pigs averaged 23.3 lb and were 35 d of age.

Starting on d 14 after weaning, six experimental diets (Table 2) were fed for 21 days. All diets were fed in meal form. Using the apparent ileal digestible amino acid coefficients and ME values determined in previous experiments, diets were formulated to .95% apparent digestible lysine using extruded-expelled SBM with and without hulls. Pigs fed these diets were compared with those fed corresponding corn-46.5% CP (without hulls) or 44% CP (with hulls) solvent-extracted SBM diets with added soy oil. Soy oil was added to equalize ME across comparative treatments. These extruded-expelled SBM products were processed by the Insta-Pro Express™ extruder/press system, using the Model 2500 Insta-Pro Dry extruder and Model 1500 Continuous Horizontal Press. Extruder temperatures and production rates for extruded-expelled SBM with and without hulls were 312 and 316°F and 1,875 and 1,925 lb/hr, respectively. Extruded-expelled SBM products originated from the same batches used in the digestibility and energy determination experiments previously conducted at Kansas State University. A fifth diet containing an alternative expelled SBM source (Soyplus) was formulated to a similar total lysine content (1.10% total lysine). Pigs fed this diet were compared with those fed a 44% CP SBM diet formulated to the same lysine, methionine, Ca, P, and crude fat concentrations. The last two diets were formulated on a calculated total nutrient basis using values obtained from NRC (1998) or chemical analysis, because digestibility values were not available for the alternative expelled SBM product.

Pigs were housed in an environmentally controlled nursery at the Kansas State University Swine Teaching and Research Center. Each pen was 4 × 5 ft and contained one nipple waterer and one four-hole self-feeder to provide ad libitum access to water and feed. Pigs were weighed and feed disappearance was determined weekly to calculate ADG, ADFI, and F/G.

Data were analyzed as a randomized complete block design with pen as the experimental unit. Contrast statements were used to compare the growth performance of pigs fed the different extruded-expelled SBM sources with their respective solvent-extracted SBM and added soy oil diets formulated to the same ME concentration or crude fat level.

## Results and Discussion

From d 0 to 14 after weaning when pigs were fed a common diet, ADG, ADFI, and F/G were .70 lb, .88 lb, and 1.25, respectively. For any time period or the cumulative study, pigs fed either extruded-expelled SBM source with or without hulls (Insta-Pro) had similar ($P > .14$) ADG, ADFI, and F/G as those fed either 46.5 or 44% CP SBM diets. From d 0 to 7, 14 to 21, or 0 to 21, pigs fed the alternative expelled soybean meal (Soyplus) had decreased ($P < .05$) ADG and poorer ($P < .004$) F/G than pigs fed 44% CP and soy oil.

Because no differences occurred in growth performance of pigs fed the Insta-Pro extruded-expelled SBM products and the conventionally processed SBM products, the extruded-expelled products can replace conventionally processed SBM and added soy oil in pig diets, based on economic feasibility. Price matrices (Tables 4, 5, 6, 7, 8, and 9) were calculated to determine the price that can be paid for the extruded-expelled products based on conventionally processed SBM and fat prices. Tables 4, 6, and 8 demonstrate the prices on an as-fed basis, and Tables 5, 7, and 9 indicate price relationships on an equal dry matter (88%) basis. Understanding the dry matter content of the products used is very important in the price relationship. The extruded-expelled SBMs contained 95 to 96% dry matter in this experiment compared to 88% dry matter for the conventionally processed SBM. If the products had a similar dry matter content, the value of the extruded-expelled SBM would be lower than when compared on an as-fed basis; however, the value is still greater than that of conventionally processed SBM. Because of its importance in establish-

ing the price relationship, the dry matter content of solvent-extracted or extruded-expelled soy products should be analyzed.

In conclusion, pigs fed diets containing Insta-Pro Express™ extruded-expelled SBM had similar growth performance to pigs fed diets formulated to similar lysine and ME values using soybean oil and conventionally processed SBM. Pigs fed diets containing Soyplus had lower ADG and higher F/G than pigs on any of the other treatments. These data illustrate the importance of proper processing when using an extruded SBM. The Insta-Pro extruded-expelled SBM products can replace conventionally processed SBM and soybean oil on an equal energy and lysine basis without influencing pig performance. Economics and availability of the products will dictate which SBM source should be used.

**Table 1. Diet Composition of Common Diets (As-Fed Basis)[a]**

| Ingredient, % | SEW | Transition |
|---|---|---|
| Corn | 39.08 | 42.43 |
| Dried whey | 25.00 | 20.00 |
| Soybean meal (46.5%) | 20.76 | 26.70 |
| Spray-dried animal plasma | 3.50 | 1.00 |
| Soy oil | 3.00 | 3.00 |
| Select menhaden fish meal | 2.50 | - |
| Spray-dried blood meal | 2.00 | 2.00 |
| Monocalcium phosphate | 1.14 | 1.61 |
| Medication | 1.00 | 1.00 |
| Limestone | .72 | .91 |
| Zinc oxide | .38 | .38 |
| Salt | .25 | .30 |
| Vitamin premix | .25 | .25 |
| L-Lysine HCl | .15 | .15 |
| Trace mineral premix | .15 | .15 |
| DL-Methionine | .12 | .12 |
| | | |
| Calculated analysis, % | | |
| Crude protein | 22.60 | 21.51 |
| Lysine | 1.60 | 1.45 |
| Methionine | .45 | .43 |
| Ca | .90 | .90 |
| P | .80 | .80 |

[a]One lb per head of SEW diet was fed, then pigs were fed the Transition diet for the remainder of the 14 d period.

**Table 2. Diet Composition of Experimental Diets (As-Fed Basis) for Six Treatments (T1-T6)**

| | Soybean Meal Source | | | | | |
|---|---|---|---|---|---|---|
| Ingredent, % | Extruded, expelled SBM without hulls[a] T1 | 46.5% CP SBM T2 | Extruded, expelled SBM with hulls[a] T3 | 44% CP SBM T4 | Soyplus[b] T5 | 44% CP SBM T6 |
| Corn | 66.01 | 60.18 | 64.37 | 55.66 | 57.24 | 58.79 |
| Extruded-expelled SBM | | | | | | |
| Without hulls | 29.60 | - | - | - | - | - |
| With hulls | - | - | 31.25 | - | - | - |
| 46.5% CP SBM | - | 32.23 | - | - | - | - |
| 44% CP SBM | - | - | - | 35.49 | - | 35.34 |
| Soyplus | - | - | - | - | 38.50 | - |
| Soy oil | - | 3.21 | - | 4.57 | - | 1.61 |
| Monocalcium phosphate | 1.54 | 1.55 | 1.54 | 1.49 | 1.39 | 1.46 |
| Limestone | 1.10 | 1.08 | 1.09 | 1.04 | 1.12 | 1.05 |
| Medication | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Salt | .35 | .35 | .35 | .35 | .35 | .35 |
| Vitamin premix | .25 | .25 | .25 | .25 | .25 | .25 |
| Trace mineral premix | .15 | .15 | .15 | .15 | .15 | .15 |
| | | | | | | |
| Calculated analysis | | | | | | |
| CP, % | 20.42 | 20.19 | 20.19 | 20.73 | 20.98 | 20.92 |
| Crude fat, % | 4.31 | 5.92 | 4.04 | 7.17 | 4.32 | 4.32 |
| ME, Mcal/lb | 1.56 | 1.56 | 1.55 | 1.55 | - | - |
| Lysine, total, % | 1.09 | 1.11 | 1.09 | 1.10 | 1.10 | 1.10 |
| Lysine, available, % | .95 | .95 | .95 | .95 | - | - |
| Methionine, % | .32 | .32 | .31 | .31 | .33 | .32 |
| Ca, % | .80 | .80 | .80 | .80 | .80 | .80 |
| P, % | .70 | .70 | .70 | .70 | .70 | .70 |

[a]Extruded-expelled, soybean meal products were processed using the Insta-Pro Express™ extruder press system.
[b]Soyplus is a commercially available, expelled, soybean meal product.

**Table 3. Influence of Different Soybean Meal Processing Techniques on Growth Performance of the Weanling Pig[a,b]**

| | Soybean Meal Source | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Extruded-expelled SBM with no hulls | 46.5% CP SBM | Extruded-expelled SBM with hulls | 44% CP SBM | Soyplus | 44% CP SBM | | Contrasts | | |
| Item | T1 | T2 | T3 | T4 | T5 | T6 | CV | 1 vs 2 | 3 vs 4 | 5 vs 6 |
| Day 0 to 7 | | | | | | | | | | |
| ADG, lb | .88 | .94 | .92 | .94 | .83 | 1.00 | 7.89 | .17 | .65 | .0003 |
| ADFI, lb | 1.54 | 1.54 | 1.53 | 1.57 | 1.56 | 1.62 | 7.72 | .96 | .56 | .41 |
| F/G | 1.75 | 1.66 | 1.66 | 1.67 | 1.89 | 1.62 | 6.84 | .17 | .84 | .0006 |
| Day 7 to 14 | | | | | | | | | | |
| ADG, lb | 1.24 | 1.22 | 1.20 | 1.14 | 1.17 | 1.25 | 9.67 | .83 | .40 | .25 |
| ADFI, lb | 2.07 | 2.05 | 2.04 | 2.00 | 2.11 | 2.13 | 7.93 | .83 | .66 | .84 |
| F/G | 1.67 | 1.68 | 1.71 | 1.80 | 1.81 | 1.71 | 8.83 | .94 | .35 | .26 |
| Day 14 to 21 | | | | | | | | | | |
| ADG, lb | 1.53 | 1.51 | 1.56 | 1.51 | 1.39 | 1.53 | 7.54 | .83 | .46 | .05 |
| ADFI, lb | 2.76 | 2.70 | 2.71 | 2.80 | 2.84 | 2.71 | 7.38 | .63 | .46 | .26 |
| F/G | 1.82 | 1.78 | 1.74 | 1.87 | 2.06 | 1.78 | 8.10 | .71 | .14 | .004 |
| Day 0 to 21 | | | | | | | | | | |
| ADG, lb | 1.21 | 1.22 | 1.22 | 1.20 | 1.13 | 1.25 | 3.62 | .71 | .36 | .0001 |
| ADFI, lb | 2.11 | 2.09 | 2.08 | 2.12 | 2.16 | 2.13 | 4.61 | .69 | .55 | .65 |
| F/G | 1.74 | 1.71 | 1.71 | 1.78 | 1.92 | 1.71 | 5.08 | .53 | .19 | .0004 |

[a]A total of 216 pigs 14 d after weaning (initially 23.25 lb and 35 d of age), six pigs per pen, and six pens per treatment (T1-T6).
[b]Pigs were fed a common diet for the first 14 d after weaning with overall ADG=.70 lb, ADFI=.88 lb, and F/G=1.25.

**Table 4. Price Matrix for Extruded-Expelled Soybean Meal without Hulls Compared to Soybean Meal on an As-Fed Basis[ab]**

| Fat Price | Soybean Meal (46.5% CP) Price ($/ton) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ($/lb) | 150 | 160 | 170 | 180 | 190 | 200 | 210 | 220 | 230 | 240 | 250 |
| .15 | 181 | 192 | 202 | 213 | 224 | 235 | 246 | 257 | 268 | 279 | 290 |
| .20 | 192 | 202 | 213 | 224 | 235 | 246 | 257 | 268 | 279 | 289 | 300 |
| .25 | 202 | 213 | 224 | 235 | 246 | 257 | 268 | 279 | 289 | 300 | 311 |
| .30 | 213 | 224 | 235 | 246 | 257 | 268 | 279 | 289 | 300 | 311 | 322 |
| .35 | 224 | 235 | 246 | 257 | 268 | 279 | 289 | 300 | 311 | 322 | 333 |

[a]Assuming corn price is $2.15/bu. Values represent the highest price that can be paid for extruded-expelled soybean meal without hulls to be economically feasible, compared to given soybean meal and fat prices.
[b]Dry matter contents of soybean meal and extruded-expelled soybean meal in this study were 88 and 96%, respectively.

**Table 5. Price Matrix for Extruded-Expelled Soybean Meal without Hulls Compared to Soybean Meal on an Equal Dry Matter Basis (88%)[a]**

| Fat Price | Soybean Meal (46.5% CP) Price, ($/ton) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ($/lb) | 150 | 160 | 170 | 180 | 190 | 200 | 210 | 220 | 230 | 240 | 250 |
| .15 | 166 | 176 | 186 | 196 | 206 | 216 | 226 | 236 | 246 | 256 | 266 |
| .20 | 176 | 186 | 196 | 206 | 216 | 226 | 236 | 246 | 255 | 265 | 275 |
| .25 | 186 | 196 | 206 | 216 | 226 | 235 | 245 | 255 | 265 | 275 | 285 |
| .30 | 196 | 206 | 215 | 225 | 235 | 245 | 255 | 265 | 275 | 285 | 295 |
| .35 | 205 | 215 | 225 | 235 | 245 | 255 | 265 | 275 | 285 | 295 | 305 |

[a]Assuming corn price is $2.15/bu. Values represent the highest price that can be paid for extruded-expelled soybean meal without hulls to be economically feasible, compared to given soybean meal and fat prices.

**Table 6. Price Matrix for Extruded-Expelled Soybean Meal with Hulls Compared to Soybean Meal on an As-Fed Basis[ab]**

| Fat Price | Soybean Meal (44% CP) Price ($/ton) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ($/lb) | 150 | 160 | 170 | 180 | 190 | 200 | 210 | 220 | 230 | 240 | 250 |
| .15 | 192 | 204 | 215 | 226 | 238 | 249 | 260 | 272 | 283 | 294 | 306 |
| .20 | 207 | 218 | 230 | 241 | 252 | 264 | 275 | 286 | 298 | 309 | 320 |
| .25 | 221 | 233 | 244 | 255 | 267 | 278 | 289 | 301 | 312 | 323 | 335 |
| .30 | 236 | 247 | 259 | 270 | 281 | 293 | 304 | 315 | 327 | 338 | 349 |
| .35 | 251 | 262 | 273 | 285 | 296 | 307 | 319 | 330 | 341 | 353 | 364 |

[a]Assuming corn price is $2.15/bu. Values represent the highest price that can be paid for extruded-expelled soybean meal with hulls to be economically feasible, compared to given soybean meal and fat prices.
[b]Dry matter content of soybean meal and extruded-expelled soybean meal in this study was 88 and 94.6%, respectively.

**Table 7. Price Matrix for Extruded-Expelled Soybean Meal with Hulls Compared to Soybean Meal on an Equal Dry Matter Basis (88%)[a]**

| Fat Price | Soybean Meal (44% CP) Price ($/ton) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ($/lb) | 150 | 160 | 170 | 180 | 190 | 200 | 210 | 220 | 230 | 240 | 250 |
| .15 | 179 | 189 | 200 | 211 | 221 | 232 | 242 | 253 | 263 | 274 | 284 |
| .20 | 192 | 203 | 214 | 224 | 235 | 245 | 256 | 266 | 277 | 287 | 298 |
| .25 | 206 | 217 | 227 | 238 | 248 | 259 | 269 | 280 | 290 | 301 | 311 |
| .30 | 220 | 230 | 241 | 251 | 262 | 272 | 283 | 293 | 304 | 314 | 325 |
| .35 | 233 | 244 | 254 | 265 | 275 | 286 | 296 | 307 | 318 | 328 | 339 |

[a]Assuming corn price is $2.15/bu. Values represent the highest price that can be paid for extruded-expelled soybean meal without hulls to be economically feasible, compared to given soybean meal and fat prices.

**Table 8. Price Matrix for Extruded-Expelled Soybean Meal with Hulls Compared to Soybean Meal on an As-Fed Basis[ab]**

| Fat Price | Soybean Meal (46.5%) Price ($/ton) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ($/lb) | 150 | 160 | 170 | 180 | 190 | 200 | 210 | 220 |
| .15 | 175 | 186 | 196 | 206 | 216 | 227 | 237 | 247 |
| .20 | 186 | 196 | 206 | 216 | 227 | 237 | 247 | 258 |
| .25 | 196 | 206 | 216 | 227 | 237 | 247 | 258 | 268 |
| .30 | 206 | 216 | 227 | 237 | 247 | 258 | 268 | 278 |
| .35 | 216 | 227 | 237 | 247 | 258 | 268 | 278 | 289 |

[a]Assuming corn price is $2.15/bu. Values represent the highest price that can be paid for extruded-expelled soybean meal without hulls to be economically feasible, compared to given soybean meal and fat prices.
[b]Dry matter contents of soybean meal and extruded-expelled soybean meal in this study were 88 and 96%, respectively.

**Table 9. Price Matrix for Extruded-Expelled Soybean Meal with Hulls to Soybean Meal on an Equal Dry Matter Basis (88%)[a]**

| Fat Price | Soybean Meal (46.5%) Price ($/ton) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ($/lb) | 150 | 160 | 170 | 180 | 190 | 200 | 210 | 220 |
| .15 | 163 | 173 | 182 | 192 | 201 | 211 | 221 | 230 |
| .20 | 173 | 182 | 192 | 201 | 211 | 221 | 230 | 240 |
| .25 | 182 | 192 | 201 | 211 | 221 | 230 | 240 | 249 |
| .30 | 192 | 201 | 211 | 220 | 230 | 240 | 249 | 259 |
| .35 | 201 | 211 | 220 | 230 | 240 | 249 | 259 | 268 |

[a]Assuming corn price is $2.15/bu. Values represent the highest price that can be paid for extruded-expelled soybean meal without hulls to be economically feasible, compared to given soybean meal and fat prices.

# EFFECTS OF A HEAT-STABLE YEAST PRODUCT IN PELLETED DIETS FOR WEANLING PIGS [1]

*C. A. Maloney, J. D. Hancock, R. H. Hines, H. Cao, C. S. Nemecek, and J. S. Park*

## Summary

The results from two experiments showed that a heat-stable yeast product survived well in diets that were steam conditioned at 158 to 176°F and pelletized. Also, inclusion of .2% yeast product resulted in a greater rate of gain and a trend for improved feed efficiency in weanling pigs.

(Key Words: Weanling Pigs, Nursery, Yeast.)

## Introduction

The effects of direct-fed microbials on animal growth and health have been of interest for many years, especially with the ever-increasing pressure to reduce (or eliminate) use of antibiotics as nonspecific growth promoters. However, growth and (or) health benefits from such products have not been demonstrated consistently in pigs. Also, the thermal processing (e.g., pelletizing) that has become part of modern feed preparation for swine and poultry is known to inactivate or kill the organisms in most direct-fed microbial products. The data in this report result from experiments designed to evaluate new yeast products for their ability to withstand the rigors of pelletizing and to determine if they affect growth performance in weanling pigs.

## Procedures

**Experiment 1.** A heat-stable (BIOSAF) or conventional (Procreatin-7) active yeast product was added as .2% of a corn-soybean meal-based diet (Phase III nursery). The diet (Table 1) was steam conditioned at atmospheric pressure with temperatures of 140, 158, 176, and 194°F. Retention time in the conditioner was approximately 10 sec for all temperature treatments. Pelleting was in a CPM Master Model HD1000 pellet mill equipped with a 1.5 in.-thick die having 5/32 in.- diameter holes. The pelletized diets were cooled with ambient temperature air in a horizontal pellet cooler. A mash conditioned at 158°F (near our normal conditioning temperature for this type of diet) without added yeast was used as the control for the experiment. Samples were taken before conditioning, after conditioning, and after cooling for determination of colony forming units (CFU) of yeast. Two independent laboratories conducted the yeast CFU analyses.

The data for CFU of yeast were transformed ($\log_{10}$) before analyses as a 2 × 4 factorial plus control. Orthogonal contrasts were used to separate treatment means with comparisons of control vs all other treatments; yeast source (heat-stable vs conventional); conditioning temperature (linear, quadratic, and cubic effects); and interactions among yeast source and conditioning temperature.

**Experiment 2.** A total of 144 pigs (average initial BW of 10.2 lb and 21 d of age) was used in a 31-d growth assay to determine the effects of the heat-stable yeast product (BIOSAF) on growth performance

[1]Appreciation is expressed to Tom Meloche and Francisco Garcia, SAF Products, Minneapolis, MN, for supplying the BIOSAF and Procreatin-7 and for financial support.

of weanling pigs. The pigs were blocked by weight and allotted to pens based on gender and ancestry. There were six pigs per pen and eight pens per treatment. The diets (Table 1) were formulated to 1.7% lysine, .9% Ca, and .8% P in Phase I (d 0 to 14) and 1.5% lysine, .8% Ca, and .7% P in Phase II (d 14 to 31). Treatments were control and .2% and .4% of the heat-stable yeast fed in both phases of the growth assay. Feed processing was the same as in Exp. 1 (i.e., the same conditioner, pellet mill, and cooler), but low conditioning temperatures were used (140°F for Phase I and 149°F for Phase II) to avoid heat damage to the milk and specialty protein products in those diets.

The pigs were housed in an environmentally controlled nursery room in 4-ft × 5-ft pens with wire mesh flooring. Room temperature initially was 90°F and was decreased by 3°F each week thereafter. The pens had a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. Pig and feeder weights were collected on d 0, 14, and 31 to allow calculation of ADG, ADFI, and F/G. Fecal samples were collected on d 13 of the assay to determine CFU of yeast, total coliforms, and *E. coli*.

## Results and Discussion

**Experiment 1.** In the conditioned mash, the control had fewer (P<.05) CFU/g than the average of the yeast treatments. As conditioning temperature was increased from 140 to 194°F, CFU of yeast (Tables 2 and 3) in the conditioned mash and cooled pellets decreased (linear effect, P<.006). However, the heat-stable product was better able to survive conditioning (P<.02) and pelleting (P<.001) than the conventional yeast product. Indeed, the heat-stable yeast generally was not affected by pelletizing with steam conditioning temperatures of at least 158°F, whereas the conventional suffered markedly with pelleting at conditioning temperatures of even 140. Thus, the technology used to manufacture the heat-stable yeast did yield a product that survived typical U.S. feed manufacturing practices (e.g., steam-conditioning temperatures of 158 to 176°F) prior to pelletizing.

**Experiment 2.** As addition of the heat-stable yeast was increased from 0 to .4% of the diet (Table 4), CFU of yeast in the pelleted diet increased (quadratic effects, P<.02). Also, CFU of yeast in the feces of pigs fed those diets increased (quadratic effect, P<.04), with a corresponding trend (linear effect, P<.08) for decreased CFU of total coliforms (Table 5). For d 0 to 14 of the growth assay (Table 6), ADG was increased by 16% with addition of .2% of the heat-stable yeast and then plateaued as the heat-stable yeast addition was increased to .4% (quadratic effect, P<.01). Also, the addition of heat-stable yeast at .2% to the Phase I diet resulted in a trend (quadratic effect, P<.06) for improved F/G compared to the control diet without added yeast. During Phase II (d 14 to 31), no differences in ADG or F/G were observed (P>.42), but overall (d 0 to 31), pigs fed diets with the heat-stable yeast still had 5% greater ADG (linear effect, P<.03) and a trend (quadratic effect, P<.09) for improved F/G.

Results from the two experiments showed that the heat-stable yeast product survived well in diets that were steam conditioned at 158 to 176°F and pelletized. Also, inclusion of .2% yeast product resulted in a greater rate of gain and a trend for improved feed efficiency in weanling pigs.

**Table 1. Diet Composition**

| Ingredient, % | Phase I[a] (d 0 to 14) | Phase II[b] (d 14 to 31) | Diet for Pelleting Experiment |
|---|---|---|---|
| Corn | 32.28 | 49.15 | 62.17 |
| Soybean meal ( 46.5% CP ) | 20.53 | 21.25 | 30.43 |
| Spray-dried whey | 20.00 | 20.00 | ---- |
| Lactose | 10.00 | ---- | ---- |
| Spray-dried wheat gluten | 5.00 | ---- | ---- |
| Spray-dried plasma protein | 4.00 | ---- | ---- |
| Spray-dried blood meal | 1.00 | 2.00 | ---- |
| Soybean oil | 2.00 | 3.00 | 3.00 |
| Monocalcium phosphate | 1.68 | 1.27 | 1.55 |
| Limestone | .77 | .70 | .90 |
| L-Lysine HCl | .35 | .41 | .10 |
| DL-Methionine | .20 | .18 | .05 |
| Threonine | .03 | .04 | ---- |
| Tryptophan | .01 | ---- | ---- |
| Salt | .20 | .30 | .30 |
| KSU vitamin premix | .25 | .25 | .25 |
| KSU mineral premix | .15 | .15 | .15 |
| Antibiotic | 1.00[c] | 1.00[d] | 1.00[d] |
| Zinc oxide | .35 | ---- | ---- |
| $CuSO_4$ | ---- | .10 | .10 |
| Chromic oxide | .20 | .20 | ---- |
| Total | 100.00 | 100.00 | 100.00 |

[a]Formulated to 1.7% lysine, .9 % Ca, and .8% P.
[b]Formulated to 1.5% lysine, .8% Ca, and .7% P.
[c]Provided 150 g of apramycin / ton of feed.
[d]Provided 50 g of carbadox / ton of feed.

**Table 2. Effects of Conditioning Temperature on Live Yeast Cell Counts (*Saccharomyces cerevisiae*, Sc. 47) in Processed Feed[a]**

| | Control | Conventional (cond temp., $^{o}$F) | | | | Heat-Stable (cond temp., $^{0}$F) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item[b] | (no yeast 158$^{0}$F) | 140 | 158 | 176 | 194 | 140 | 158 | 176 | 194 | SE |
| Conditioned mash, $\log_{10}$ | 3.0 | 7.1 | 5.6 | 2.2 | 1.2 | 7.3 | 6.5 | 5.9 | 2.2 | .7 |
| Cooled pellets, $\log_{10}$ | 3.1 | 3.5 | 1.4 | 2.6 | 1.3 | 6.3 | 6.4 | 5.1 | 3.2 | .7 |

[a]The same corn-soybean meal-based diet was used for all treatments.
[b] Yeast counts before the conditioner were: control 4.5 $\log_{10}$; heat-stable 6.8 $\log_{10}$; conventional 7.3 $\log_{10}$.

**Table 3. Probability Values for the Conditioning Experiment ($\log_{10}$ data)**

| | Probability (P <) Values[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Item | Control vs others | Conventional vs Heat-stable | Temp. linear | Yeast × linear | Temp. quadratic | Yeast × quadratic | Temp. cubic | Yeast × cubic |
| Conditioned mash | .05 | .02 | .001 | .28 | .27 | .14 | .78 | .14 |
| Cooled pellets | .44 | .001 | .006 | .27 | .57 | .19 | .27 | .18 |

**Table 4. CFU of a Heat-Stable Yeast Product in Diets for the Growth Assay[a]**

| | Heat-Stable, % | | | | P Values | |
|---|---|---|---|---|---|---|
| Item | 0 | .2 | .4 | SE | Lin | Quad |
| Phase I CFU/g, $\log_{10}$ | 1.7 | 6.6 | 6.9 | .3 | .002 | .008 |
| Phase II CFU/g, $\log_{10}$ | 1.6 | 6.8 | 7.5 | .4 | .003 | .02 |

[a]Samples cooled pellets collected before sacking.

**Table 5. Yeast, Total Coliform, and *E. coli* Concentrations in Pig Feces[a]**

| | Heat-Stable, % | | | | P Values | |
|---|---|---|---|---|---|---|
| Item | 0 | .2 | .4 | SE | Lin | Quad |
| Yeast CFU/g, $\log_{10}$ | 2.9 | 4.6 | 4.7 | .3 | .001 | .04 |
| Coliform CFU/g, $\log_{10}$ | 3.3 | 2.3 | 2.0 | .5 | .08 | .56 |
| *E. coli* CFU/g, $\log_{10}$ | 3.2 | 2.1 | 1.7 | .6 | .11 | .66 |

[a]Samples were taken from 4 pigs/pen on d 13 of the growth assay and pooled within pen.

**Table 6. Effects of a Heat-Stable Yeast Product on Growth Performance of Weaned Pigs[a]**

| | Heat-Stable, % | | | | P Values | |
|---|---|---|---|---|---|---|
| Item | 0 | .2 | .4 | SE | Lin | Quad |
| Phase I (d 0 to 14) | | | | | | |
| ADG, lb | .69 | .80 | .77 | .02 | .02 | .01 |
| ADFI, lb | 1.09 | 1.04 | 1.07 | .02 | .63 | .28 |
| F/G | 1.58 | 1.30 | 1.39 | .07 | .08 | .06 |
| Phase II (d 14 to 31) | | | | | | |
| ADG, lb | 1.11 | 1.11 | 1.14 | .02 | .43 | .66 |
| ADFI, lb | 1.94 | 1.89 | 1.94 | .02 | .93 | .08 |
| F/G | 1.75 | 1.70 | 1.70 | .05 | .69 | .69 |
| Overall (d 0 to 31) | | | | | | |
| ADG, lb | .92 | .97 | .97 | .01 | .03 | .18 |
| ADFI, lb | 1.54 | 1.49 | 1.54 | .02 | .81 | .09 |
| F/G | 1.67 | 1.54 | 1.59 | .04 | .15 | .09 |

[a]A total of 144 weanling pigs (six pigs per pen and eight pens per treatment) with an average initial BW of 10.2 lb and 21 d of age.

# INFLUENCE OF *SPIRULINA PLATENSIS* ON GROWTH PERFORMANCE OF WEANLING PIGS [1]

***G. S. Grinstead, M. D. Tokach [2], R. D. Goodband, J. L. Nelssen, J. Sawyer, K. Maxwell, R. Stott, and A. Moser***

## Summary

We conducted three experiments to evaluate the influence of an algal feed additive, *Spirulina platensis*, on weanling pig performance. Two experiments conducted under commercial production conditions indicated a response to *Spirulina platensis* in meal-based diets but not pelleted diets. Another experiment concluded that *Spirulina platensis* tended to improve F/G early in the trial but not for cumulative performance. Results of these three experiments suggest that *Spirulina platensis* added at low inclusions to the diet may enhance performance. However, the results lacked consistency across experiments and warrant further investigation.

(Key Words: Starter Pigs, Algae, Performance.)

## Introduction

*Spirulina platensis* is algal derived feed additive that was first introduced to the human food market as a dietary supplement. It is organically grown in specialized ponds so it is free of contaminants. Research has indicated that *Spirulina platensis* can enhance the immune system. Growing poults fed *Spirulina platensis* had increased weight gain. These poults also had increased spleen and thymus weights. Only one experiment with *Spirulina* has been conducted with swine. That trial evaluated *Spirulina maxima* as a replacement for dried skim milk. Results indicated that pigs fed high levels of *Spirulina maxima* (14% of the diet) had similar growth performance as those fed dried skim milk. Because of polymorphism, there is confusion regarding naming of *Spirulena*. *Maxima* and *platensis* are considered synonyms for the same plant. *Spirulena platensis* should have a pH of 10 to 11 and contain at least .9% gamma linoleic acid.

Because of the lack of data on the influence of *Spirulina platensis* in diets for pigs, we conducted these experiments to evaluate the effects of low concentrations of *Spirulina platensis* in the diet on weanling pig performance.

## Procedures

**Experiment 1.** A total of 203 pigs (initially 8.1 lb and 11 to 12 d of age) was used in a 28-d growth trial. Pigs were blocked by weight and allotted randomly to one of four dietary treatments. There were eight or nine pigs/pen and six pens/treatment. Pigs were fed a control diet or diets containing .2, .5 or 2% *Spirulina platensis* replacing soybean meal on an equal lysine basis. The amino acid profile of *Spirulina platensis* appears to be relatively similar to that of soybean meal (Table 1). The trial was divided into three phases to approximate a nutritional program similar to that used in commercial produc-

[1]The authors thank Earthrise Co., Tollhouse, CA for providing the *Spirulina platensis* used in these experiments and for partial financial support. The authors also thank Adam McNabb and Eichman Brothers, St.George, KS for the use of facilities and animals for Exps. 1 and 3 and Henry's LTD, Longford, KS for the use of animals for Exp. 2.

[2]Northeast Area Extension Office, Manhattan, KS.

tion: an SEW phase from d 0 to 7, a Transition phase from d 7 to 14, and Phase II from d 14 to 28. Pigs remained on their respective dietary treatments in all three phases.

**Table 1. Composition of *Spirulina platensis* and Soybean Meal [a]**

| Item , % | *Spirulina platensis*[b] | Soybean Meal[c] |
|---|---|---|
| Protein | 62.0 | 47.5 |
| Fat | 5.5 | 3.0 |
| Amino Acids | | |
| Arginine | 4.30 | 3.48 |
| Cystine | .60 | .74 |
| Histidine | 1.00 | 1.28 |
| Isoleucine | 3.50 | 2.16 |
| Leucine | 5.40 | 3.66 |
| Lysine | 2.90 | 3.02 |
| Methionine | 1.40 | .67 |
| Phenylalanine | 2.80 | 2.39 |
| Threonine | 3.20 | 1.85 |
| Tryptophan | .90 | .65 |
| Tyrosine | 3.00 | 1.82 |
| Valine | 4.00 | 2.27 |

[a]Values shown on an as-fed basis.
[b]Amino acid levels provided by Earthrise.
[c]Amino acid levels were adapted from NRC (1998).

The SEW basal diet was a pelleted corn-soybean meal diet containing 6.7% spray-dried animal plasma, 1.65% spray-dried blood meal, 6% select menhaden fish meal, 25% dried whey, and 5% lactose. This diet was formulated to contain 1.6% lysine, .9% Ca, and .8% P (Table 2). The pelleted transition diet contained 2.5% spray-dried animal plasma, 2.5% spray-dried blood meal, 2.5% select menhaden fish meal, and 20% dried whey and was formulated to contain 1.5% lysine, .9% Ca, and .8% P (Table 2). The Phase II basal diet contained 2.5% spray-dried blood meal and 10% dried whey and was formulated to contain 1.3% lysine, .9% Ca, and .8% P (Table 2). The Phase II diet was the only diet fed in a meal form. *Spirulina platensis* replaced soybean meal (.2%, .5%, and 2%) in the control diet to provide the additional experimental treatments.

Pigs were housed in an environmentally controlled nursery in 5 × 5 ft pens on a commercial farm in N.E. Kansas. All pens contained one self-feeder and two nipple waters to provide ad libitum access to feed and water. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 7, 14, 21, and 28 after weaning.

**Experiment 2.** A total of 180 weanling pigs (initially 12.4 lbs. and 18d of age) was used in a 42-d growth trial to examine the effects of duration of feeding *Spirulina platensis* on growth performance. Pigs were blocked by weight and allotted randomly to one of six dietary treatments. There were five pigs/pen and six pens/treatment. The trial was divided into four phases: the SEW phase was d 0 to 7, a Transition phase from d 7 to 14, Phase II from d 14 to 28, and Phase III from d 28 to 35 after weaning. Dietary treatment groups consisted of a control group (no *Spirulina*) fed for 6 weeks; *Spirulina* (.1%) fed for 6 weeks; and *Spirulina* (.2%) fed for 1, 2, 4, or 6 weeks. At the end of each *Spirulina* feeding regimen, pigs were switched to the control diet for the remainder of the experiment.

Pigs were fed a control diet or diets containing .1 or .2% *Spirulina platensis* replacing soybean meal on an equal lysine basis. The basal diets used for the SEW, Transition, and Phase II periods had the same compositions as those used in Exp 1. The Phase III diet was a corn-soybean meal-based diet that contained 10% dried whey. Diets fed in this experiment were in a meal form and contained no medication or zinc oxide.

Pigs were housed in an environmentally controlled nursery in 5 × 5 ft pens. All pens contained one self-feeder and one nipple waterer to provide ad libitum access to feed and water. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 7, 14, 21, 28, 35, and 42 after weaning.

**Experiment 3.** A total of 192 weanling pigs (initially 8.8 lbs and 11 to 12 d of age) were used in a 28-d growth trial. This experiment was implemented to examine the effects of pig performance when diets containing *Spirulina platensis* were fed in a pellet or meal form. Pigs were blocked by weight and allotted randomly to one of four dietary treatments. There were eight pigs/pen and six pens/treatment. The basal diets, feeding regimen, and experimental procedures were the same as those used in Exp.1. Pigs also were housed in the same facilities as in Exp.1. Pigs were fed a control diet in meal and pellet form or diets containing .2% *Spirulina platensis* in a pellet or meal form. *Spirulina platensis* replaced soybean meal in the control diet on an equal lysine basis.

## Results and Discussion

**Experiment 1.** From d 0 to 7 after weaning when pigs were fed SEW diets, increasing *Spirulina platensis* had no effect on growth performance relative to those fed the control diet (Table 3). However, increasing *Spirulina platensis* tended to numerically improve ADG, ADFI, and F/G (linear, P<.11, .15, and .15 respectively). The linear response was predominantly within the three levels of *Spirulina platensis*, with pigs fed .2% having the poorest ADG and those fed 2.0% having the greatest ADG. Direct comparisons of each level to the control diet revealed that none of the treatments was different.

During the Transition phase (d 7 to 14 after weaning), no differences in ADG were observed. Daily feed intake increased, then decreased and then increased again (cubic, P<.01) in response to increasing *Spirulina platensis*. Pigs fed .2% *Spirulina platensis* had greater ADFI than those fed the control diet during this period. Feed efficiency tended to become poorer (linear, P<.10) with increasing *Spirulina platensis*.

From d 14 to 28 after weaning, ADG and ADFI responded in a cubic (P<.05) fashion with increasing *Spirulina platensis*. Pigs fed .2% *Spirulina platensis* had the best ADG which was greater than those fed the control diet or diet containing .5% *Spirulina platensis*. Pigs fed 2.0% *Spirulina platensis* had intermediate ADG. Daily feed intake was greatest for pigs fed either .2 or 2.0% *Spirulina platensis* compared with those fed .5%, with those fed the control diet having intermediate ADFI. Feed efficiency was not affected by *Spirulina platensis*.

For the entire experimental period (d 0 to 28 after weaning), ADG (cubic, P<.10) and ADFI (cubic, P<.05) increased, then decreased and then increased again with increasing *Spirulina platensis* (Table 3). Pigs fed either .2 or 2.0% had greater ADG and ADFI than pigs fed .5% *spirulina platensis*, whereas those fed the control diet had intermediate performance. Feed efficiency was unaffected by *Spirulina platensis*.

The results of this experiment suggest that increasing *Spirulina platensis* had no beneficial effect of growth performance during the first 2 weeks of the study when pigs were fed pelleted diets. However, from d 14 to 28, pigs fed .2% *Spirulina platensis* had increased ADG compared with those fed the control diet. The improved growth performance happens to coincide with feeding pigs meal-based diets. We speculate that perhaps high temperatures associated with the pelleting process may have damaged or inactivated the *Spirulina platensis*. Similar heat stability problems have been observed when pigs have been fed supplemental enzymes or probiotics that have been subjected to thermal processing. Because of the improved ADG observed when pigs were fed .2% *Spirulina platensis* in a meal diet, additional research warranted to confirm this positive response. The other possible explanation for the improved performance from d 14 to 28 with no response from d 0 to 14 is the duration of feeding of the *Spirulina platensis*. If the improvement in growth performance was mediated through an enhancement in immune function, a delayed response would be expected. This possibility also warranted further exploration. Therefore, Exp. 2 was conducted to examine the length of time that diets containing *Spirulina platensis* should be fed, and Exp.3 was

conducted to compare the effects of pig performance when pigs were fed meal or pellet diets containing *Spirulina platensis*.

**Experiment 2.** From d 0 to 14 after weaning, no significant differences in ADG or F/G were observed among the treatment groups. However, pigs fed either .1% or .2% *Spirulina platensis* had numerically higher ADG than pigs fed the control diet. The 20% numerical improvement in ADG was a result of an increase in ADFI (P<.10) found in both the .1% and .2% *Spirulina platensis* treatment groups (Table 4).

From d 7 to 14 and d 0 to 14 after weaning, no differences in ADG or ADFI were observed. However, pigs fed .2% *Spirulina platensis* for 2 weeks had higher numerical ADG than pigs fed the control diet or pigs fed the diet containing .1% *Spirulina platensis*. Pigs fed .2% *Spirulina platensis* for only 1 week had intermediate performance. Feed efficiency was not affected from d 7 to 14. However, from d 0 to 14 after weaning, pigs fed diets containing .1% or .2% *Spirulina platensis* for 2 weeks tended to have better F/G (P<.11) than the control group or pigs fed .2% for only 1 week.

From d 14 to 28 or d 0 to 28 after weaning, pigs fed .2% *Spirulina platensis* for only 2 weeks had higher ADFI (P<.01) than any other treatment group. The increase in ADFI numerically improved ADG. Pigs fed diets containing .1% or .2% *Spirulina platensis* for the entire 28 days had better feed efficiency (P<.02) than any other treatment group.

For the fifth and sixth week after weaning, d 28 to 42, no differences in ADG, ADFI, or F/G were observed in pigs fed the control diet; .1% *Spirulina platensis*; or .2% *Spirulina platensis* for 1, 2, 4, or 6 weeks.

For the entire experimental period (d 0 to 42 after weaning), no differences in ADG or ADFI were found. However, pigs fed .2% *Spirulina platensis* for 2 weeks tended to have numerically higher daily feed intake. Pigs fed .1% *Spirulina platensis* had numerically the best feed efficiency (P<.09) of any treatment group. However, direct comparisons of the .1% *Spirulina platensis* results revealed only a difference from the .2% *Spirulina platensis* in diets fed for either 1 or 2 weeks (Table 4).

**Experiment 3.** From d 0 to 7 after weaning when pigs were fed SEW diets, *Spirulina platensis* had no direct effect on ADG or F/G. An effect of *Spirulina platensis* by pellet interaction (P<.05) on ADFI was observed. Pigs fed the pelleted *Spirulina platensis* diet had lower feed intakes, whereas pigs fed a meal *Spirulina platensis* diet had higher feed intakes. Pigs fed pelleted diets showed a significant significant improvement in feed efficiency (P<.01) (Table 5).

During the Transition period, d 7 to 14 after weaning, feeding *Spirulina platensis* had no effect on ADG, ADFI, or F/G. From d 0 to 14 after weaning, adding *Spirulina platensis* to pelleted diets tended to decrease ADG (*Spirulina* × pellet, P<.10), whereas adding *Spirulina platensis* to meal diets tended to slightly improve ADG. Pigs fed *Spirulina platensis* in a pellet form had lower ADFI (P<.06) than any other treatment group. Pigs fed pelleted diets had better F/G (P<.01) than pigs fed meal-based diets.

From d 14 to 28 after weaning, ADG, ADFI, and F/G were not affected significantly by *Spirulina platensis*. However, pigs fed *Spirulina platensis* had numerically better ADG compared to the pigs fed the control diets. For the entire experimental period, d 0 to 28 after weaning, *Spirulina platensis* fed in either a meal or pellet form had no effect on ADFI or F/G. Average daily gain means tended to be greater in pigs fed *Spirulina platensis*. Pig weights also tended to be slightly higher in pigs fed *Spirulina platensis*, with the heaviest pigs from the *Spirulina platensis* meal diet. A pellet by *Spirulina platensis* interaction occurred for pig weight on d 14 (P<.05) and 21 (P<.04). Adding *Spirulina platensis* to pelleted diets decreased pig weight, whereas adding it to meal diets increased pig weight.

The improvements in pig performance from feeding *Spirulina platensis* were predominately in meal-based diets. This suggests that *Spirulina platensis* may not be heat stable under pelleting processes. The results of these three experiments suggest that *Spirulina platensis*, added at low inclusions to the diet, can enhance performance. However, the improvements lack consistency across experiments. These inconsistencies warrant further investigation.

**Table 2. Compositions of Basal Diets**

| | Dietary Phases | | | |
|---|---|---|---|---|
| Ingredient, % | SEW [a] | Transition [b] | Phase II [c] | Phase III [d] |
| Corn | 33.57 | 39.88 | 58.18 | 65.06 |
| Dried whey | 25.00 | 20.00 | 10.00 | 10.00 |
| Soybean meal [e] | 12.47 | 23.24 | 24.56 | 30.54 |
| Spray-dried animal plasma | 6.70 | 2.50 | --- | --- |
| Soybean oil | 6.00 | 5.00 | --- | --- |
| Select menhaden fish meal | 6.00 | 2.50 | --- | --- |
| Lactose | 5.00 | --- | --- | --- |
| Spray-dried blood meal | 1.75 | 2.50 | 2.50 | 2.50 |
| Antibiotic [f] | 1.00 | 1.00 | 1.00 | --- |
| Monocalcium phosphate | .76 | 1.28 | 1.64 | 1.53 |
| Limestone | .48 | .75 | 1.00 | .97 |
| Zinc oxide | .38 | .38 | .25 | --- |
| Vitamin premix | .25 | .30 | .25 | .25 |
| Salt | .20 | .25 | .25 | .35 |
| L-Lysine HCl | .15 | .15 | .15 | .15 |
| Trace mineral premix | .15 | .15 | .15 | .15 |
| DL-methionine | .15 | .13 | .08 | .01 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 |

[a]Diets were formulated to contain 1.7% lysine, .48% methionine, .9% Ca, .8% P and were fed from d 0 to 7 postweaning.
[b]Diets were formulated to contain 1.6% lysine, .44% methionine, .9% Ca, .8% P and were fed from d 7 to 14 postweaning.
[c]Diets were formulated to contain 1.3% lysine, .36% methionine, .85% Ca, .75% P and were fed from 14 to 28 postweaning.
[d]Diets were formulated to contain 1.2% lysine, .32% methionine, .75% Ca, .70% P and were fed from d 28 to 42 postweaning (Exp.2).
[e]*Spirulina platensis* replaced soybean meal on an equal lysine basis.
[f] Provided 50 g/ton carbodox.

**Table 3. Effect of Increasing *Spirulina* Fed from d 0 to 28 after Weaning on Pig Performance (Exp.1)[a]**

| | | *Spirulina*, % | | | | P < | | |
|---|---|---|---|---|---|---|---|---|
| Item | Control | .2 | .5 | 2.0 | SEM | Lin. | Quad. | Cubic |
| Day 0 to 7 | | | | | | | | |
| ADG, lb | .28[ab] | .25[a] | .27[ab] | .31[b] | .02 | .11 | .45 | .35 |
| ADFI, lb | .32[ab] | .31[a] | .32[ab] | .33[b] | .01 | .15 | .79 | .36 |
| F/G | 1.14[ab] | 1.22[a] | 1.18[ab] | 1.07[b] | .06 | .15 | .39 | .42 |
| Day 7 to 14 | | | | | | | | |
| ADG, lb | .49 | .52 | .53 | .48 | .02 | .44 | .68 | .22 |
| ADFI, lb | .53[a] | .58[b] | .54[ab] | .56[ab] | .02 | .69 | .76 | .10 |
| F/G | 1.07[a] | 1.10[ab] | 1.14[ab] | 1.18[b] | .05 | .10 | .38 | .96 |
| Day 0 to 14 | | | | | | | | |
| ADG, lb | .39 | .39 | .37 | .39 | .02 | .73 | .51 | .72 |
| ADFI, lb | .42 | .44 | .43 | .44 | .01 | .40 | .87 | .31 |
| F/G | 1.09 | 1.14 | 1.16 | 1.14 | .03 | .55 | .25 | .70 |
| Day 14 to 21 | | | | | | | | |
| ADG, lb | .53 | .55 | .46 | .53 | .03 | .92 | .17 | .25 |
| ADFI, lb | .84[a] | .87[a] | .77[b] | .89[a] | .02 | .12 | .02 | .07 |
| F/G | 1.59 | 1.59 | 1.66 | 1.65 | .06 | .67 | .66 | .75 |
| Day 21 to 28 | | | | | | | | |
| ADG, lb | .74[c] | .88[d] | .82[cd] | .83[cd] | .04 | .55 | .25 | .06 |
| ADFI, lb | 1.18[a] | 1.29[b] | 1.18[a] | 1.25[ab] | .03 | .52 | .83 | .03 |
| F/G | 1.61[c] | 1.47[d] | 1.45[d] | 1.51[cd] | .04 | .56 | .02 | .30 |
| Day 14 to 28 | | | | | | | | |
| ADG, lb | .63[c] | .71[d] | .64[c] | .68[cd] | .02 | .62 | .99 | .04 |
| ADFI, lb | 1.01[cd] | 1.08[c] | .98[d] | 1.07[c] | .03 | .28 | .24 | .03 |
| F/G | 1.60 | 1.52 | 1.52 | 1.56 | .05 | .97 | .26 | .44 |
| Day 0 to 28 | | | | | | | | |
| ADG, lb | .51[ab] | .55[a] | .51[b] | .53[ab] | .01 | .60 | .73 | .08 |
| ADFI, lb | .72[ab] | .76[a] | .70[b] | .75[a] | .02 | .34 | .41 | .05 |
| F/G | 1.40 | 1.39 | 1.39 | 1.40 | .02 | .74 | .56 | .70 |
| Avg. Pig wt, lb | | | | | | | | |
| d 0 | 8.08 | 8.11 | 8.07 | 8.08 | .03 | .51 | .16 | .52 |
| d 7 | 10.02[ab] | 9.85[a] | 9.95[ab] | 10.24[b] | .16 | .13 | .51 | .28 |
| d 14 | 13.47 | 13.51 | 13.27 | 13.57 | .29 | .47 | .63 | .81 |
| d 21 | 17.20 | 17.34 | 16.51 | 17.62 | .33 | .45 | .83 | .76 |
| d 28 | 22.37 | 23.49 | 22.22 | 23.41 | .51 | .43 | .48 | .28 |

[a]A total of 203 weanling pigs (initially 8.1 lb and 11 to 12 d of age) with 8 or 9 pigs per pen and six replications per treatment.
[ab]Means in the same row with different letters are different (P<.10).
[cd]Means in the same row with different letters are different (P<.05).

**Table 4. Effects of Feeding Duration of *Spirulina platensis* on Weanling Pig Performance (Exp.2)**[1]

| | | | | *Spirulina* Removed on Day 3 | | | | |
|---|---|---|---|---|---|---|---|---|
| Item | 0 | .1% | .2% [2] | 7 | 14 | 28 | SEM | P < |
| Day 0 to 7 | | | | | | | | |
| ADG, lb | .23 | .29 | .29 | | | | .028 | .32 |
| ADFI, lb | .28[a] | .35[b] | .34[b] | | | | .020 | .07 |
| F/G | 1.25 | 1.23 | 1.25 | | | | .112 | .99 |
| Day 7 to 14 | | | | | | | | |
| ADG, lb | .62 | .61 | .68 | .66 | | | .032 | .26 |
| ADFI, lb | .71 | .65 | .74 | .77 | | | .041 | .29 |
| F/G | 1.15 | 1.06 | 1.09 | 1.18 | | | .039 | .20 |
| Day 0 to 14 | | | | | | | | |
| ADG, lb | .42 | .45 | .49 | .46 | | | .027 | .29 |
| ADFI, lb | .50 | .50 | .54 | .54 | | | .027 | .40 |
| F/G | 1.17 | 1.11 | 1.11 | 1.19 | | | .028 | .11 |
| Day 14 to 28 | | | | | | | | |
| ADG, lb | 1.07 | 1.06 | 1.06 | 1.05 | 1.11 | | .028 | .72 |
| ADFI, lb | 1.60[cd] | 1.51[c] | 1.57[cd] | 1.64[d] | 1.77[e] | | .042 | .004 |
| F/G | 1.52[ce] | 1.41[d] | 1.47[cd] | 1.56[e] | 1.60[e] | | .037 | .02 |
| Day 0 to 28 | | | | | | | | |
| ADG, lb | .74 | .76 | .77 | .76 | .81 | | .024 | .46 |
| ADFI, lb | 1.05[cd] | 1.01[c] | 1.04[cd] | 1.09[d] | 1.18[e] | | .032 | .01 |
| F/G | 1.42[c] | 1.32[d] | 1.35[d] | 1.44[c] | 1.46[c] | | .026 | .004 |
| Day 28 to 42 | | | | | | | | |
| ADG, lb | 1.55 | 1.55 | 1.49 | 1.55 | 1.56 | 1.51 | .049 | .89 |
| ADFI, lb | 2.52 | 2.51 | 2.45 | 2.56 | 2.55 | 2.53 | .061 | .80 |
| F/G | 1.63 | 1.63 | 1.65 | 1.66 | 1.64 | 1.68 | .025 | .68 |
| Day 0 to 42 | | | | | | | | |
| ADG, lb | 1.01 | 1.02 | 1.00 | 1.02 | 1.06 | 1.01 | .029 | .81 |
| ADFI, lb | 1.54 | 1.51 | 1.51 | 1.58 | 1.64 | 1.52 | .037 | .14 |
| F/G | 1.52[cd] | 1.48[c] | 1.50[c] | 1.55[d] | 1.55[d] | 1.50[c] | .020 | .09 |
| Avg. pig wt, lb | | | | | | | | |
| d 0 | 12.46 | 12.43 | 12.42 | | | | .025 | .47 |
| d 7 | 14.10 | 14.47 | 14.44 | | | | .055 | .40 |
| d 14 | 18.40 | 18.78 | 19.25 | 18.96 | | | .380 | .36 |
| d 21 | 23.55 | 23.98 | 24.46 | 24.21 | 25.72 | | .585 | .17 |
| d 28 | 33.32 | 33.68 | 34.56 | 33.72 | 35.04 | | .928 | .69 |
| d 35 | 43.29 | 44.18 | 45.68 | 43.78 | 45.67 | 45.61 | 1.27 | .61 |
| d 42 | 55.00 | 55.33 | 56.17 | 55.37 | 56.83 | 56.34 | 1.42 | .93 |

[1]A total of 180 weanling pigs (initially 12.4 lb and 18 d of age) with five pigs per pen and six replications per treatment.
[2]Represents mean of all pens remaining on .2% *Spirulina* for each respective weight period.
[3]Represents mean of all pens previously fed .2% *Spirulina* then switched to the control diet.
[a,b]Means in the same row with different letters are different (P<.05).
[c,d,e]Means in the same row with different letters are different (P<.10).

**Table 5. Effects of Feeding *Spirulina platensis* in a Meal or Pelleted Diet on Weanling Pig Performance (Exp.3)[1]**

| | Meal | | Pelleted | | | P < | | |
|---|---|---|---|---|---|---|---|---|
| Item | Control | *Spirulina* | Control | *Spirulina* | SEM | Pellet | *Spirulina* | Spir × Pell [2] |
| Day 0 to 7 | | | | | | | | |
| ADG, lb | .24 | .25 | .31 | .28 | .023 | .07 | .84 | .29 |
| ADFI, lb | .37[a] | .39[b] | .35[a] | .32[c] | .012 | .009 | .70 | .03 |
| F/G | 1.55 | 1.55 | 1.16 | 1.20 | .096 | .002 | .84 | .82 |
| Day 7 to 14 | | | | | | | | |
| ADG, lb | .56 | .57 | .55 | .55 | .024 | .36 | .74 | .68 |
| ADFI, lb | .76 | .76 | .70 | .65 | .029 | .002 | .36 | .41 |
| F/G | 1.36 | 1.35 | 1.26 | 1.19 | .063 | .02 | .42 | .51 |
| Day 0 to 14 | | | | | | | | |
| ADG, lb | .39[d] | .41[de] | .43[e] | .41[de] | .012 | .15 | .89 | .10 |
| ADFI, lb | .56[a] | .57[a] | .52[b] | .49[c] | .014 | .001 | .50 | .06 |
| F/G | 1.41 | 1.40 | 1.21 | 1.18 | .043 | .001 | .61 | .80 |
| Day 14 to 28 | | | | | | | | |
| ADG, lb | .75 | .77 | .69 | .73 | .023 | .05 | .19 | .67 |
| ADFI, lb | 1.08 | 1.10 | 1.01 | 1.04 | .025 | .02 | .38 | .98 |
| F/G | 1.45 | 1.44 | 1.48 | 1.42 | .046 | .97 | .46 | .69 |
| Day 0 to 28 | | | | | | | | |
| ADG, lb | .57 | .59 | .56 | .57 | .012 | .16 | .18 | .78 |
| ADFI, lb | .82 | .84 | .76 | .76 | .015 | .001 | .60 | .49 |
| F/G | 1.44 | 1.43 | 1.37 | 1.33 | .036 | .05 | .50 | .71 |
| Avg. pig wt, lb | | | | | | | | |
| d 0 | 8.82 | 8.83 | 8.81 | 8.84 | .008 | .99 | .89 | .33 |
| d 7 | 10.44 | 10.62 | 10.98 | 10.78 | .178 | .07 | .95 | .31 |
| d 14 | 14.33[a] | 14.63[a] | 15.11[b] | 14.61[a] | .192 | .07 | .60 | .05 |
| d 21 | 17.82[a] | 18.89[b] | 19.05[b] | 18.50[ab] | .359 | .26 | .49 | .04 |
| d 28 | 24.76 | 25.36 | 24.73 | 24.79 | .411 | .48 | .44 | .53 |

[1]A total of 180 weanling pigs (initially 8.8 lbs and 11 to 12 d of age) with eight pigs per pen and six replications per treatment.
[2]Interaction of *Spirulina* and pellets.
[abc]Means in the same row are different (P<.10).
[de]Means in the same row are different (P<.05).

# SUCROSE AND MOLASSES IN SIMPLE OR COMPLEX DIETS FOR NURSERY PIGS

***I. Mavromichalis, J. D. Hancock, R. H. Hines, J. M. DeRouchey, B. W. Senne, S. P. Sorrell, and H. Cao***

## Summary

Three experiments were conducted to determine the effects of replacing lactose with sucrose and molasses in simple and complex diets for nursery pigs. In general, complex diets supported greater growth performance than simple diets, and added lactose and sucrose gave greater efficiency of growth than diets without added sugars. Comparisons among sugar sources indicated that lactose, sucrose, and molasses were utilized equally well by weanling pigs.

(Key Words: Lactose, Sucrose, Molasses, Nursery Pigs.)

## Introduction

The efficacy of milk products in diets for nursery pigs is well documented. Also, recent research suggests that a source of highly digestible protein can be mixed with crystalline lactose and used to replace milk products (dried whey and dried skim milk) in weaner diets. However, if price or availability necessitates the replacement of milk products, the same problem usually applies to crystalline lactose.

Sucrose long has been suggested as an energy source and appetite enhancer when used in nursery diets. The same is true for molasses, although high dietary concentrations generally are not recommended. Also, sucrose and cane molasses are readily accessible throughout much of the world. Thus, the experiments reported herein were designed to determine the effects of replacing lactose with sucrose and cane molasses on growth performance and nutrient digestibility in nursery pigs.

## Procedures

In the first experiment, 210 (PIC line 326 sire × C15 and C22 dams) weanling pigs with an average initial BW of 10 lb were used in a 30-d growth assay to determine the effects of replacing 50 and 100% (wt/wt) of crystalline lactose with cane sucrose and cane molasses (Carmilglo®). The diets (Table 1) were formulated to 1.7 and 1.5% lysine for d 0 to 10 and 11 to 35, respectively, and were fed in pelleted form.

The pigs were grouped by initial BW and assigned to treatments based on sex and ancestry. There were four pigs per pen in two blocks, five pigs per pen in two blocks, and six pigs per pen in four blocks for a total of eight pens per treatment. The pigs were housed in an environmentally controlled nursery facility with plastic-coated flooring. Each pen (5 ft × 5 ft) was equipped with a five-hole self-feeder and nipple waterer to allow ad libitum consumption of feed and water. Temperature at animal level was at 90°F initially and lowered by 3°F each week thereafter. Pigs and feeders were weighed at initiation and the end of each phase to allow calculation of ADG, ADFI, and F/G.

All data were analyzed as a randomized complete block design using the GLM procedures of SAS. Pen was the experimental unit. Treatment comparisons were made using the orthogonal contrasts: 1) lactose vs other sugars; 2) sucrose vs molasses; 3) 50 vs 100% replacement of lactose; and 4) sucrose vs molasses × 50 vs 100% replacement of lactose.

In our second experiment, a total of 150 nursery pigs (PIC genotype) with an average

initial BW of 15 lb was used in a 30-d growth assay. In this experiment, sucrose and molasses were larger percentages of the diet than in Exp. 1 because whey protein concentrate was used in place of dried whey, thus giving more room in the formula for crystalline lactose (20% in Exp. 2 vs 10% in Exp. 1). A negative control, with no added sugar, also was included in Exp. 2 to determine if, indeed, the carbohydrates sources were beneficial to the pigs. The diets (Table 2) were formulated to 1.7 and 1.5 % lysine for d 0 to 10 and 10 to 35, respectively, and fed in pelleted form.

**Table 1. Compositions of the Basal Diets for Experiment 1**

| Item | Phase 1 | Phase 2 |
|---|---|---|
| Ingredient, % | | |
| Corn | 26.67 | 37.33 |
| Soybean meal (46.5% CP) | 26.62 | 38.57 |
| Edible grade whey | 20.00 | 5.00 |
| Lactose[a] | 10.00 | 10.00 |
| Spray-dried porcine plasma | 4.00 | - |
| Spray-dried wheat gluten | 4.00 | - |
| Spray-dried blood cells | 2.00 | 2.00 |
| Soybean oil | 2.00 | 2.00 |
| Monocalcium phosphate | 1.50 | 1.91 |
| Limestone | .94 | 1.02 |
| Salt | .10 | .20 |
| Vitamin premix | .25 | .25 |
| Trace trace mineral premix | .15 | .15 |
| Zinc oxide | .39 | .39 |
| Lysine HCl | .22 | - |
| DL-methionine | .16 | .18 |
| Antibiotic[b] | 1.00 | 1.00 |
| Calculated analysis | | |
| Crude protein (N × 6.25), % | 25.7 | 23.7 |
| Lysine, % | | |
| Ca, % | 1.7 | 1.5 |
| P, % | .9 | .9 |
| Digestible energy, kcal/lb | .8 | .8 |
| | 1,579 | 1,589 |

[a]Replaced by 50 and 100% sucrose or molasses.
[b]Provided 75 mg of apramycin per lb of complete diet.

The pigs were grouped by initial BW and assigned to treatments based on sex and ancestry. There were five pigs per pen and five pens per treatment. Pig management was the same as for Exp. 1.

All data were analyzed as a randomized complete block design with the treatment comparisons: 1) no sugar vs other treatments; 2) lactose vs other sugars; 3) sucrose vs molasses; 4) 50 vs 100% replacement of lactose; and 5) sucrose vs molasses × 50 vs 100% replacement of lactose.

In our third experiment, a total of 180 nursery pigs (PIC genetics) with an average initial BW of 14 lb was used in a 30-d growth assay. Treatment main effects were diet complexity (simple and complex) and carbohydrate source (no sugar, lactose, and sucrose) arranged as a 2 × 3 factorial. The diets (Table 3) were formulated to 1.7 and 1.5% lysine for d 0 to 10 and 10 to 35, respectively, and were fed in pelleted form.

The pigs were grouped by initial BW and assigned to treatments based on sex and ancestry. There were six pigs per pen and five pens per treatment. The pigs were housed and managed in the same environmentally controlled nursery facility used in Exps. 1 and 2. On d 10, fecal samples were collected (four pigs per pen) by rectal massage. The fecal samples were pooled within pen, dried, and ground, and concentrations of Cr, DM, and N in the feces and diets were determined.

The data were analyzed as a randomized complete block design with a 2 × 3 factorial arrangement of treatments and pen as the experimental unit. Treatment comparisons were made using the orthogonal contrasts: 1) simple vs complex; 2) no sugar vs sugars; 3) simple vs complex × no sugar vs sugars; 4) lactose vs sucrose; and 5) simple vs complex × lactose vs sucrose.

## Results and Discussion

For d 0 to 10 of our first experiment, no differences (P>.17) were observed for ADG, ADFI, or F/G when lactose was replaced

with either sucrose or molasses (Table 4). Researchers have suggested that increasing diet sweetness, by adding sugars enhances palatability and feed intake postweaning. In our experiment, the diets were of a complex nature and were consumed readily, thus decreasing the likelihood that a "sweetener" would affect feed intake. For d 10 to 30 and overall (d 0 to 30), ADG and ADFI also were not affected by replacing lactose with sucrose or molasses (P>.15), but a trend (P<.10) occurred for slightly better F/G in pigs fed lactose.

Compared to diets with sucrose, those with molasses supported greater overall ADG (P<.02). This was caused primarily by the reduction in performance when 100% of the lactose was replaced with sucrose (sucrose vs molasses × 50 vs 100% replacement, P<.01).

In our second experiment, a negative (no added sugar) control was included in the treatment design, and a higher concentration of dietary lactose, sucrose, and molasses was included in the diets. For d 0 to 10, replacing half or all of the lactose with sucrose and the molasses had no effect on ADG, ADFI, and F/G (P>.35) (Table 5). However, the pigs fed the diet without added carbohydrate sources had growth performance that was similar to pigs fed the more complex diets (P>.33).

For d 10 to 30 and overall (d 0 to 30), added lactose, sucrose, and molasses had no effect (P>.29) on growth performance of the pigs. Comparisons within the added carbohydrate sources indicated a trend (P<.10) for greater overall ADG when sucrose and molasses were used to replace lactose. However, replacing 100% of the lactose with sucrose and molasses reduced F/G for d 10 to 30 (P<.01) and 0 to 30 (P<.04) compared with 50% replacement.

The observation of no negative effect of feeding a diet without dietary simple sugars is in contrast with much published research. Therefore, our pigs, consuming a high-nutrient density diet in relatively high amounts (attributable to the presence of spray-dried porcine plasma, blood meal, and wheat gluten), apparently performed well without highly digestible sources of carbohydrates in their diets.

Our third and final experiment was designed to test the hypothesis that the presence of simple sugars in complex diets may be without benefit (e.g. as in Exp. 2) and to demonstrate the possible effects of easily digested carbohydrates in simple nursery diets. Consuming a complex diet from d 0 to 10 postweaning resulted in greater ADG (P<.01) and ADFI (P<.01) and in a trend (P<.06) for better F/G (Table 6). The F/G was better (P<.04) when sugars were added to the diets, and pigs fed diets with sucrose tended to have better F/G than pigs fed diets with lactose (P<.07).

For the overall period (d 0 to 30), a trend (P<.06) occurred for improved ADG and F/G with complex diets and improved F/G with inclusion of sugars (P<.01). Also, apparent digestibilities of DM (P<.04) and N (P<.05) were greater for the complex versus simple diets. An interaction (P<.03) of diet complexity × sugar additions resulted from better F/G when simple sugars where included in complex diets. Finally, diets with sucrose tended to be used more efficiently (P<.07) than diets with lactose. Also, apparent digestibilities of DM (P<.04) and N (P<.05) were greater for the complex versus simple diets.

Based on our three experiments, complex diets were of great benefit in the period immediately postweaning.

**Table 2. Compositions of the Basal Diets for Experiment 2**

| | Phase 1 | | Phase 2 | |
|---|---|---|---|---|
| Item | No added sugar | Crystalline lactose | No added sugar | Crystalline lactose |
| Ingredient, % | | | | |
| Corn | 53.05 | 28.97 | 57.23 | 40.46 |
| Soybean meal (46.5% CP) | 21.59 | 25.62 | 31.69 | 34.39 |
| Lactose[a] | - | 20.00 | - | 14.00 |
| Whey protein concentrate (34% CP) | 8.00 | 8.00 | 2.00 | 2.00 |
| Spray-dried porcine plasma | 4.00 | 4.00 | - | - |
| Spray-dried wheat gluten | 4.00 | 4.00 | - | - |
| Spray-dried blood cells | 2.00 | 2.00 | 2.00 | 2.00 |
| Soybean oil | 2.00 | 2.00 | 2.00 | 2.00 |
| Monocalcium phosphate | 1.79 | 1.98 | 1.50 | 1.64 |
| Limestone | 1.15 | 1.05 | 1.08 | 1.01 |
| Salt | .25 | .25 | .35 | .35 |
| Vitamin premix | .25 | .25 | .25 | .25 |
| Trace mineral premix | .15 | .15 | .15 | .15 |
| Zinc oxide | .39 | .39 | .26 | .26 |
| Lysine HCl | .24 | .16 | .21 | .16 |
| DL-methionine | .14 | .18 | .20 | .23 |
| Threonine | - | - | .08 | .10 |
| Antibiotic[b] | 1.00 | 1.00 | 1.00 | 1.00 |
| Calculated analysis | | | | |
| Crude protein (N × 6.25), % | 25.7 | 25.5 | 22.5 | 22.3 |
| Lysine, % | 1.7 | 1.7 | 1.5 | 1.5 |
| Ca, % | .9 | .9 | .8 | .8 |
| P, % | .8 | .8 | .7 | .7 |
| Digestible energy, kcal/lb | 1,591 | 1,619 | 1586 | 1,606 |

[a]Replaced by 50 and 100% sucrose or molasses.
[b]Provided 75 mg of apramycin per lb of complete diet.

**Table 3. Composition of Diets for Experiment 3**

| | Phase I | | | | Phase 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Simple | | Complex | | Simple | | Complex | |
| Item | No added sugar | Crystalline lactose | No added sugar | Crystalline lactose | No added sugar | Crystalline lactose | No added sugar | Crystalline lactose |
| Ingredient, % | | | | | | | | |
| Corn | 54.37 | 29.57 | 52.80 | 28.70 | 60.21 | 43.28 | 57.23 | 40.46 |
| Soybean meal (46.5% CP) | 33.36 | 38.15 | 21.59 | 25.62 | 30.73 | 33.61 | 31.69 | 34.39 |
| Lactose[a] | - | 20.00 | - | 20.00 | - | 14.00 | - | 14.00 |
| Whey protein concentrate (34% CP) | - | - | 8.00 | 8.00 | - | - | 2.00 | 2.00 |
| Fish meal | 5.00 | 5.00 | - | - | 2.00 | 2.00 | - | - |
| Spray-dried porcine plasma | - | - | 4.00 | 4.00 | - | - | - | - |
| Spray-dried wheat gluten | - | - | 4.00 | 4.00 | - | - | - | - |
| Spray-dried blood cells | - | - | 2.00 | 2.00 | - | - | 2.00 | 2.00 |
| Soybean oil | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Monocalcium phosphate | 1.37 | 1.55 | 1.79 | 1.98 | 1.31 | 1.44 | 1.50 | 1.64 |
| Limestone | .75 | .65 | 1.15 | 1.05 | .94 | .87 | 1.08 | 1.01 |
| Salt | .25 | .25 | .25 | .25 | .35 | .35 | .35 | .35 |
| Vitamin premix | .25 | .25 | .25 | .25 | .25 | .25 | .25 | .25 |
| Trace mineral premix | .15 | .15 | .15 | .15 | .15 | .15 | .15 | .15 |
| Zinc oxide | .39 | .39 | .39 | .39 | .26 | .26 | .26 | .26 |
| Lysine HCl | .41 | .31 | .24 | .16 | .42 | .37 | .21 | .16 |
| DL-methionine | .26 | .29 | .14 | .18 | .22 | .25 | .20 | .23 |
| Threonine | .19 | .19 | - | - | .16 | .17 | .08 | .10 |
| Chromic oxide[b] | .25 | .25 | .25 | .25 | - | - | - | - |
| Antibiotic[c] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Calculated analysis | | | | | | | | |
| Crude protein (N × 6.25), % | 23.9 | 23.9 | 25.7 | 25.5 | 21.3 | 21.1 | 22.5 | 22.3 |
| Lysine, % | 1.7 | 1.7 | 1.7 | 1.7 | 1.5 | 1.5 | 1.5 | 1.5 |
| Ca, % | .9 | .9 | .9 | .9 | .8 | .8 | .8 | .8 |
| P, % | .8 | .8 | .8 | .8 | .7 | .7 | .7 | .7 |
| Digestible energy, kcal/lb | 1,591 | 1,619 | 1,591 | 1,619 | 1,584 | 1,604 | 1,586 | 1,606 |

[a]Replaced with sucrose.
[b]Used as an indigestible marker.
[c]Provided 75 mg of apramycin per lb of complete diet.

**Table 4. Effects of Replacing Lactose with Sucrose and a Cane Molasses on Growth Performance in Nursery Pigs (Exp. 1)[a]**

| | | Ingredient Replacing Lactose[b] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Crystaline | Sucrose | | Molasses | | | Contrasts[c] | | | |
| Item | Lactose | 50% | 100% | 50% | 100% | SE | 1 | 2 | 3 | 4 |
| Day 0 to 10 | | | | | | | | | | |
| ADG, lb | .65 | .67 | .65 | .66 | .71 | .02 | -[d] | .13 | - | .05 |
| ADFI, lb | .62 | .63 | .64 | .65 | .70 | .02 | - | .04 | .15 | - |
| F/G | .95 | .94 | .99 | 1.00 | .98 | .07 | - | - | - | - |
| Day 10 to 30 | | | | | | | | | | |
| ADG, lb | 1.04 | 1.03 | .93 | 1.02 | 1.03 | .02 | .15 | .06 | .05 | .02 |
| ADFI, lb | 1.37 | 1.42 | 1.35 | 1.41 | 1.44 | .03 | - | - | - | - |
| F/G | 1.32 | 1.38 | 1.46 | 1.38 | 1.40 | .05 | .11 | - | - | - |
| Day 0 to 30 | | | | | | | | | | |
| ADG, lb | .90 | .91 | .81 | .89 | .91 | .01 | - | .02 | .03 | .01 |
| ADFI, lb | 1.11 | 1.15 | 1.09 | 1.15 | 1.19 | .02 | - | .11 | - | .13 |
| F/G | 1.23 | 1.26 | 1.34 | 1.29 | 1.30 | .04 | .10 | - | - | - |

[a]A total of 210 pigs (four to six pigs/pen and eight pens/treatment) with an avg initial BW of 10 lb.
[b]Replaced lactose on a wt/wt basis. All diets contained 20% dried whey, which provided 14% lactose.
[c]Contrasts were: 1) lactose vs other sugars; 2) sucrose vs molasses; 3) 50 vs 100% replacement of lactose; and 4) sucrose vs molasses × 50 vs 100% replacement of lactose.
[d]Dashes indicate P>.15.

**Table 5. Effects of Replacing Lactose with Sucrose and a Cane Molasses on Growth Performance in Nursery Pigs (Exp. 2)[a]**

| | | | Ingredient Replacing Lactose[b] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Sucrose | | Molasses | | | Contrasts[c] | | | | | |
| Item | No Added Sugar | Crystalline Lactose | 50% | 100% | 50% | 100% | SE | 1 | 2 | 3 | 4 | 5 |
| Day 0 to 10 | | | | | | | | | | | | |
| ADG, lb | .76 | .76 | .81 | .81 | .77 | .81 | .04 | -[d] | - | - | - | - |
| ADFI, lb | .88 | .81 | .89 | .86 | .85 | .85 | .06 | - | - | - | - | - |
| F/G | 1.15 | 1.07 | 1.11 | 1.06 | 1.1 | 1.05 | .16 | - | - | - | - | - |
| Day 10 to 30 | | | | | | | | | | | | |
| ADG, lb | 1.35 | 1.27 | 1.44 | 1.28 | 1.35 | 1.34 | .04 | - | .11 | - | .09 | .13 |
| ADFI, lb | 2.15 | 2.17 | 2.35 | 2.26 | 2.13 | 2.33 | .07 | - | - | - | - | .10 |
| F/G | 1.60 | 1.71 | 1.63 | 1.76 | 1.58 | 1.74 | .04 | - | - | - | .01 | - |
| Day 0 to 30 | | | | | | | | | | | | |
| ADG, lb | 1.16 | 1.09 | 1.22 | 1.13 | 1.15 | 1.16 | .04 | - | .10 | - | - | - |
| ADFI, lb | 1.73 | 1.72 | 1.85 | 1.80 | 1.7 | 1.84 | .06 | - | - | - | - | .13 |
| F/G | 1.49 | 1.57 | 1.51 | 1.59 | 1.47 | 1.58 | .05 | - | - | - | .04 | - |

[a]A total of 150 pigs (five pigs/pen and five pens/treatment) with an avg initial BW of 15 lb.
[b]Replaced lactose on a wt/wt basis.
[c]Contrasts were: 1) no sugar vs other treatments; 2) lactose vs other sugars; 3) sucrose vs molasses; 4) 50 vs 100% replacement of lactose; and 5) sucrose vs molasses × 50 vs 100% replacement of lactose.
[d]Dashes indicate P>.15.

**Table 6. Effects of Replacing Lactose with Sucrose in Simple and Complex Diets on Growth Performance and Apparent Nutrient Digestibility in Nursery Pigs (Exp. 3)[a]**

| | Simple | | | Complex | | | | Contrasts[c] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | No added sugar | Crystalline lactose | Sucrose[b] | No added sugar | Crystalline lactose | Sucrose[b] | SE | 1 | 2 | 3 | 4 | 5 |
| d 0 to 10 | | | | | | | | | | | | |
| ADG, lb | .56 | .51 | .60 | .72 | .67 | .72 | .04 | .01 | -[d] | - | .12 | - |
| ADFI, lb | .57 | .52 | .58 | .73 | .63 | .63 | .04 | .01 | .07 | - | - | - |
| F/G | 1.02 | 1.02 | .96 | 1.01 | .95 | .88 | .08 | .06 | .04 | - | .07 | - |
| d 10 to 30 | | | | | | | | | | | | |
| ADG, lb | 1.30 | 1.24 | 1.30 | 1.26 | 1.27 | 1.30 | .04 | - | - | - | - | - |
| ADFI, lb | 1.70 | 1.62 | 1.67 | 1.72 | 1.63 | 1.66 | .04 | - | .11 | - | - | - |
| F/G | 1.31 | 1.30 | 1.29 | 1.37 | 1.28 | 1.28 | .02 | - | .02 | .04 | - | - |
| d 0 to 30 | | | | | | | | | | | | |
| ADG, lb | 1.05 | .99 | 1.07 | 1.08 | 1.07 | 1.11 | .03 | .06 | - | - | .09 | - |
| ADFI, lb | 1.33 | 1.25 | 1.31 | 1.39 | 1.30 | 1.32 | .05 | - | .06 | - | - | - |
| F/G | 1.26 | 1.26 | 1.23 | 1.28 | 1.21 | 1.19 | .02 | .06 | .01 | .03 | .07 | - |
| Nutrient digestibility (d 10), % | | | | | | | | | | | | |
| DM | 82.0 | 81.3 | 82.2 | 84.6 | 82.5 | 84.2 | 1.0 | .04 | - | - | - | - |
| N | 73.3 | 77.1 | 70.1 | 79.6 | 76.5 | 78.0 | 2.2 | .05 | - | - | - | .12 |

[a]A total of 180 pigs (six pigs/pen and five pens/treatment) with an avg initial BW of 14 lb.
[b]Replaced lactose on a wt/wt basis.
[c]Contrasts were: 1) simple vs complex; 2) no sugar vs sugars; 3) simple vs complex × no sugar vs sugars; 4) lactose vs sucrose; and 5) simple vs complex × lactose vs sucrose.
[d]Dashes indicate P>.15.

# EFFECTS OF DIFFERENT FAT SOURCES ON GROWTH PERFORMANCE OF EARLY-WEANED PIGS [1]

*M. De La Llata, R. D. Goodband, M. D. Tokach [2], J. L. Nelssen, S. S. Dritz [3], G. S. Grinstead, J. C. Woodworth, and J. S. Herbert [4]*

## Summary

One hundred and eighty weanling pigs (initially 14.6 lb and 21 ± 2 d of age) were used in a 35 d growth trial to evaluate different dietary fat sources. Treatments consisted of a control diet (no added fat) or diets with 5% added fish oil, soybean oil, choice white grease, or a combination of 2.5% fish oil and 2.5% choice white grease. The diets were fed in two phases (d 0 to 14 and d 14 to 35 after weaning). Diets were fed in a meal form and formulated to a similar lysine:calorie ratio. From d 0 to 14 after weaning, pigs fed either soybean oil or fish oil had improved ADG and F/G compared to pigs fed the control diet, with those fed choice white grease or the blend of choice white grease and fish oil having intermediate performance. From d 14 to 35 and for the cumulative period (d 0 to 35) after weaning, neither added fat nor source affected ADG; however, F/G was improved for pigs fed any of the fat sources compared with those fed the control diet. These results suggest that adding 5% fat to the diet from d 0 to 35 after weaning improved F/G approximately 8%. Fish oil, soybean oil, and choice white grease appear to be similar in their value as fat sources for weanling pigs.

(Key Words: Fat Source, Early-Weaned Pigs, Performance.)

## Introduction

Recent research has demonstrated that early-weaned pigs (17 to 21 days of age) do not efficiently utilize added dietary fat for the first 14 days after weaning. However, from day 14 to 35 after weaning, added dietary fat generally increases daily gain, reduces feed intake, and improves feed efficiency. The cause for this poorer utilization of dietary fat immediately after weaning is uncertain. This is especially puzzling because sow's milk, which is high in fat, is utilized efficiently by pigs. Research from Ohio State University has shown that the concentration of intestinal fatty acid binding proteins decreases at weaning, then gradually increases after 10 to 14 days. This pattern of fatty acid binding protein secretion appears to be correlated with the observed changes in growth performance. Nonetheless, 4 to 8% fat is added to diets fed to pigs immediately after weaning. This inclusion is to provide a lubricant to facilitate pelleting and reduce dust of diets containing high concentrations of milk and other specialty protein products. Although many different fat sources have been evaluated in diets for early-weaned pigs, little is known about fish oil. Therefore, the objective of this study was to compare the effects of menhaden fish oil with those of other fat sources on starter pig performance.

---

[1]The authors thank Omega Proteins, Inc. Hammond, LA for providing the fish oil, special select menhaden fish meal, and partial financial support for this project.

[2]Northeast Area Extension Office, Manhattan, KS.

[3]Food Animal Health and Management Center.

[4]Omega Proteins, Inc., Hammond, LA.

## Procedures

One hundred and eighty weanling pigs (PIC L326 × C22, initially 14.6 lb and 21 ± 2 d of age) were blocked by weight and allotted to one of five dietary treatments in a randomized complete block design. There were six pigs per pen and six pens per treatment. The dietary treatments consisted of a control diet (no added fat) and diets containing 5% added fish oil, soybean oil, or choice white grease or a combination of 2.5% fish oil and 2.5% choice white grease. Diets were formulated and fed in two phases (Table 1). The control diet fed from weaning to d 14 (phase I) was formulated to contain 1.50% lysine, whereas the diet fed from d 14 to 35 (phase II) was formulated to contain 1.30% lysine. Added-fat diets were formulated to maintain the same lysine:calorie ratio among treatments. Furthermore, because of the unsaturated fatty acid profile of menhaden fish oil, an extra 60,000 IU vitamin E (100,000 IU total) was added as a precaution to all diets. All other nutrients met or exceeded the NRC (1998) estimates. Diets were fed in a meal form.

Pigs were housed at the Kansas State University Swine Research and Teaching Center. Pigs were allowed ad libitum access to food and water through a dry feeder and one nipple waterer per pen. Fat samples were taken for chemical analysis, and fatty acid profile was determined (Table 2). Pigs were weighed and feed disappearance was determined weekly for the 35-d trial. Average daily gain, ADFI, and F/G were the response criteria.

## Results and Discussion

Chemical analysis of the fat sources is presented in Table 2. Results suggest that all fat sources were of high quality; however, the fish oil had a greater initial peroxide value than either the soybean oil or choice white grease. The choice white grease had the highest free fatty acid concentration at 9.5%. Over 12% unidentified peaks occurred in the fish oil fatty acid analysis. These peaks are likely omega 3 and 6 fatty acids.

From d 0 to 14 after weaning, pigs fed either soybean oil or fish oil had greater ADG compared to those fed the control diet ($P<.05$). Pigs fed either choice white grease or the blend of fish oil and choice white grease had intermediate ADG. Pigs fed soybean oil had greater ADFI than those fed either the control diet or diets containing choice white grease or the blend of choice white grease and fish oil, and pigs fed fish oil had intermediate ADFI. Feed efficiency was not affected by dietary treatment; however, pigs fed fish oil had numerically improved feed efficiency relative to pigs fed the control diet.

From d 14 to 35, ADG was not affected by dietary treatment. Daily feed intake and F/G were lowest for pigs fed either choice white grease or the blend of choice white grease and fish oil compared to those fed the control diet ($P<.05$). Pigs fed either fish oil or soybean oil had intermediate ADFI and F/G.

For the overall period, ADG was not affected by dietary treatment. Pigs fed diets containing choice white grease or the blend of choice white grease and fish oil had decreased ADFI ($P>.05$) compared with those fed the control diet or diet containing fish oil. Feed efficiency was not different among pigs fed any of the fat sources but was improved for pigs fed all of fat sources compared to those fed the control diet ($P<.05$). These results suggest that 5% added fat from fish oil, soybean oil, or choice white grease will improve feed efficiency in early-weaned pigs from weaning to d 35.

Contrary to previous research evaluating weanling pigs fed added fat, ADG was increased during the first 14 days after weaning by adding 5% fish oil or soybean oil to the diet. In addition, pigs fed fish oil had very similar growth performance compared to those fed other fat sources, despite the fact that the fish oil had a high initial peroxide value. During phase II and for the overall period, added fat, regardless of the source, improved feed efficiency.

In summary, these results suggest that fish oil is an effective fat source relative to soybean oil or choice white grease for use in diets of early-weaned pigs. Adding 5% fat to starter pig diets resulted in an 8% improvement in overall F/G.

**Table 1. Diet Composition[a]**

| | Day 0 to 14 | | Day 14 to 35 | |
|---|---|---|---|---|
| Item, % | Control | 5% Fat | Control | 5% Fat |
| Corn | 50.96 | 41.91 | 57.73 | 48.63 |
| Dried whey | 20.00 | 20.00 | 10.00 | 10.00 |
| Soybean meal (46.5 % CP) | 15.35 | 19.42 | 23.37 | 27.45 |
| Fat source[b] | --- | 5.00 | --- | 5.00 |
| Spray-dried animal plasma | 5.00 | 5.00 | --- | --- |
| Menhaden fish meal | 2.50 | 2.50 | 5.00 | 5.00 |
| Spray-dried blood meal | 1.75 | 1.75 | --- | --- |
| Monocalcium phosphate | 1.23 | 1.23 | 1.04 | 1.04 |
| Limestone | .82 | .80 | .62 | .60 |
| Mecadox | 1.00 | 1.00 | 1.00 | 1.00 |
| Zinc oxide | .375 | .375 | .375 | .375 |
| Vitamin premix | .25 | .25 | .25 | .25 |
| Vitamin E premix | .15 | .15 | .15 | .15 |
| Trace mineral premix | .15 | .15 | .15 | .15 |
| Salt | .20 | .20 | .30 | .30 |
| L-lysine HCl | .15 | .15 | .15 | .15 |
| DL-methionine | .125 | .125 | --- | .035 |
| Ethoxyquin | --- | .005 | --- | .005 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 |
| | | | | |
| Calculated analysis | | | | |
| Crude protein, % | 21.4 | 22.5 | 20.3 | 21.4 |
| Lysine, % | 1.50 | 1.60 | 1.30 | 1.40 |
| ME, Mcal/lb | 1.46 | 1.55 | 1.46 | 1.56 |
| Lysine/ME:(g/Mcal) | 4.66 | 4.69 | 4.04 | 4.07 |
| Ca, % | .90 | .90 | .85 | .85 |
| P, % | .80 | .80 | .75 | .75 |

[a]During each phase, treatments included a control; 5% added soybean oil, fish oil, or choice white grease; or a blend of 2.5% choice white grease and 2.5% fish oil.

**Table 2. Chemical Analysis of Fat Sources[a]**

| Item | Fat Source | | |
|---|---|---|---|
| | Soybean oil | Fish oil | Choice white grease |
| Moisture and volatiles, % | .57 | .28 | .70 |
| Insoluble impurities, % | .30 | .04 | .50 |
| Unsaponifiable matter, % | .98 | 1.03 | 1.12 |
| M.I.U. %, | 1.85 | 1.35 | 2.32 |
| Free fatty acids, % | 2.10 | 2.80 | 9.50 |
| Peroxide value, Meq/kg | .95 | 9.18 | < .20 |
| Fatty acid profile, % | | | |
| C 10:0 Methyl caprate | — | — | .1 |
| C 12:0 Methyl laurate | — | .1 | .1 |
| C 13:0 Methyl tridecanoate | — | .1 | — |
| C 14:0 Methyl myristate | .1 | 9.2 | 1.5 |
| C 14:1 Methyl myristoleate | — | .2 | .2 |
| C 15:0 Methyl pentadecanoate | — | .5 | .2 |
| C 15:1 Methyl pentadecanoate | — | .1 | .1 |
| C 16:0 Methyl palmitate | 10.9 | 17.6 | 22.8 |
| C 16:1 Methyl palmitoleate | — | 11.6 | 3.0 |
| C 17:0 Methyl heptadecanoate | — | 3.1 | .6 |
| C 17:1 Methyl heptadecanoleate | — | 2.4 | .4 |
| C 18:0 Methyl stereate | 4.4 | 4.1 | 13.5 |
| C 18:1 Methyl oleate | 24.5 | 12.4 | 39.4 |
| C 18:2 Methyl linoleate | 51.7 | 2.3 | 14.7 |
| C 18:3 Methyl linolenate | 7.5 | 1.9 | 1.5 |
| C 20:0 Methyl arachydate | .2 | 3.1 | .3 |
| C 20:1 Methyl eicosenoate | .1 | 1.8 | .8 |
| C 20:2 Methyl eicosadienoate | .1 | .5 | .4 |
| C 20:3 Methyl eicosatrienoate | — | .2 | .1 |
| C 20:4 Methyl arachinodate | — | .9 | — |
| C 22:0 Methyl behenate | .4 | 1.0 | .3 |
| C 22:1 Methyl erucate | — | 14.2 | — |
| C 24:0 Methyl lignocerate | .1 | .5 | — |
| Unidentified peaks[b] | — | 12.2 | — |

[a]Values (as-fed basis) represent one sample.
[b]Unidentified peaks likely represent omega 3 and 6 fatty acids typically contained in fish oils.

**Table 3. Effects of Different Fat Sources on the Growth Performance of Weanling Pigs[a]**

| Item | Control | Fish Oil | Soybean Oil | Choice White Grease | Choice White Grease + Fish Oil | SEM |
|---|---|---|---|---|---|---|
| Day 0 to 14 | | | | | | |
| ADG, lb | .74[b] | .84[cd] | .85[d] | .77[bc] | .78[bcd] | .025 |
| ADFI, lb | .94[b] | .98b[c] | 1.06[c] | .93[b] | .97[b] | .026 |
| F/G | 1.30 | 1.17 | 1.25 | 1.24 | 1.25 | .038 |
| Day 14 to 35 | | | | | | |
| ADG, lb | 1.37 | 1.40 | 1.39 | 1.37 | 1.40 | .027 |
| ADFI, lb | 2.25[b] | 2.18[bc] | 2.08[cd] | 2.03[d] | 2.06[d] | .037 |
| F/G | 1.64[b] | 1.56[c] | 1.49[cd] | 1.48[d] | 1.47[d] | .026 |
| Day 0 to 35 | | | | | | |
| ADG, lb | 1.12 | 1.18 | 1.17 | 1.13 | 1.15 | .021 |
| ADFI, lb | 1.72[b] | 1.70[b] | 1.67[bc] | 1.59[c] | 1.62[cd] | .025 |
| F/G | 1.55[b] | 1.44[c] | 1.42[c] | 1.41[c] | 1.41[b] | .017 |

[a]One hundred and eighty pigs (PIC L326 × C22, initially 14.6 lb and 21 d of age) were used with six pigs per pen and six replications (pens) per treatment.
[b,c,d]Means with different superscript differ (P<.05).

# EFFECTS OF INCREASING PANTOTHENIC ACID ON GROWTH PERFORMANCE OF SEGREGATED EARLY-WEANED PIGS [1]

*G. S. Grinstead, R. D. Goodband, J. L. Nelssen, M. D. Tokach [2], S. S. Dritz [3], and R. Stott*

## Summary

We conducted a 28-d experiment to evaluate effects of increasing dietary pantothenic acid on growth performance of segregated early-weaned pigs. Pigs (initially 8.8 ± 2.2 lb and 11 ± 2 d of age) were fed a control diet (no added pantothenic acid) or the control diet with 30, 60, and 120 ppm of added pantothenic acid. Increasing pantothenic acid increased ADG and ADFI linearly from d 0 to 14 after weaning. However, from d 14 to 28 after weaning, pigs fed 60 mg/kg of added pantothenic acid tended to have the greatest ADG and ADFI. For the cumulative period (d 0 to 28 after weaning), ADG and ADFI increased linearly with increasing added pantothenic acid. The linear improvements in weanling pig growth performance observed with increasing pantothenic acid indicated that current NRC (1998) requirement estimates may be too low. Because of the wide range of pantothenic acid concentrations used in our study, additional research is warranted to define a more precise requirement estimate.

(Key Words: Starter Pigs, Pantothenic Acid, Performance.)

## Introduction

Recent research has demonstrated that segregated early weaning (10 to 17 days of age) results in minimizing the transmission of disease from the sow to the pig. Pigs raised in these high-health environments have been shown to have increased growth rate compared to those conventionally weaned. Part of the improved growth performance has been linked to decreased immune system activation. Studies have found that these pigs may require increased dietary nutrient fortification to support the increased protein deposition. Recently, Iowa State University demonstrated that high-health pigs had a greater requirement for B-complex vitamins (approximately 4 times NRC, (1988) estimates) compared to pigs with chronic immune system activation. However, these pigs were fed a B-vitamin deficient diet for 1 week before experimental diets were fed, possibly confounding the response to vitamin supplementation. Therefore, the objective of this experiment was to evaluate the effects of increasing concentrations of one B-vitamin, pantothenic acid, on growth performance of pigs when fed from d 0 to 28 after weaning in an age-segregated production system.

## Procedures

A total of 275 weanling pigs (initially 8.8 ± 2.2 lb and 11 ± 2 d of age) was used in a 28-d growth trial. Pigs were blocked by weight and allotted randomly to one of four dietary treatments. There were seven or eight pigs per pen and nine replications per treatment. Pigs were fed a control diet (no added

[1]The authors thank Daiichi Pharmaceutical Corp., Tokyo, Japan for providing the vitamin premix and pantothenic acid and partial financial support. We also thank Adam McNess and Eichman Brothers, St. George, KS for the use of facilities and animals.

[2]Northeast Area Extension Office, Manhattan, KS.

[3]Food Animal Health and Management Center.

pantothenic acid) or diets containing 30, 60, or 120 ppm of added pantothenic acid replacing corn starch in the control diet. All pigs were fed a pelleted corn-soybean meal diet containing 25% dried whey, 6.7% spray-dried animal plasma, 6.0% select menhaden fish meal, and 5.0% lactose from d 0 to 14 after weaning (Table 1). This diet was formulated to contain 1.7% total lysine, .9% Ca, and .8% P. From d 14 to 28, all pigs were fed a corn-soybean meal diet containing 15% dried whey, 2.0% spray-dried blood meal, 2.0% select menhaden fish meal, and 1.0% spray-dried animal plasma. This diet was in a meal form and formulated to contain 1.4% lysine, .85% Ca, and .75% P. Pigs remained on their respective pantothenic acid levels throughout the 28-d experiment.

Pigs were housed in an environmentally controlled nursery in 5 × 5 ft pens. All pens contained one self-feeder and two nipple waterers to provide ab libitum access to feed and water. Average daily gain, ADFI, and feed:gain ratio (F/G) were determined by weighing pigs and measuring feed disappearances on d 7, 14, 21, and 28 after weaning.

Samples of each diet were collected and analyzed for pantothenic acid concentration. Given the wide range in permitted analytical variation in vitamin analysis, analyzed values were within acceptable expectations (Table 1).

## Results and Discussion

From d 0 to 7 after weaning, increasing pantothenic acid had no effect on pig growth performance (Table 2). However, from d 7 to 14 after weaning, ADG and ADFI tended to increase (linear, P = .09 and .03 respectively) with increasing pantothenic acid, but feed efficiency was not affected. For the entire period (d 0 to 14 after weaning), ADG (linear, P = .01) and ADFI (linear, P = .04) increased with increasing pantothenic acid, but feed efficiency was not affected. Although the response to increasing pantothenic acid was linear, little or no improvement in ADG or ADFI occurred for pigs fed 30 or 60 ppm, but a large increase occurred for those fed 120 ppm.

From d 14 to 28 after weaning, ADG and ADFI tended to improve with increasing pantothenic acid (quadratic, P<.10 and linear, P<.08, respectively). Unlike the response from d 0 to 14 after weaning, pigs fed 60 ppm of added pantothenic acid had the greatest ADG and ADFI.

For the entire experimental period (d 0 to 28 after weaning), ADG and ADFI increased (linear, P<.02) with increasing pantothenic acid. Although a quadratic response was not observed, the greatest increases in ADG and ADFI were observed as pantothenic acid increased from 30 to 60 ppm. Feed efficiency was unaffected by increasing pantothenic acid.

The results of this experiment suggest that increasing pantothenic acid improved growth performance of pigs weaned at 11 d of age and averaging 8.8 lb. These data suggest that current NRC (1998) estimates (12 ppm) for pantothenic acid requirements are too low for maximum pig performance. The linear response to increasing pantothenic acid observed from d 0 to 14 followed by the quadratic response observed from d 14 to 28 suggests that the pantothenic acid requirement may decrease as the pig becomes older and feed intake increases. Because of the wide range of pantothenic acid concentrations used in our study, additional research is warranted to define a more precise requirement estimate.

**Table 1. Compositions of Experimental Diets**

| Ingredients, % | Day 0 to 14 [a] | Day 14 to 28 [b] |
|---|---|---|
| Corn | 34.55 | 49.77 |
| Dried whey | 25.00 | 15.00 |
| Soybean meal | 12.39 | 22.89 |
| Spray-dried animal plasma | 6.70 | 1.00 |
| Select menhaden fish meal | 6.00 | 2.00 |
| Lactose | 5.00 | --- |
| Soybean oil | 6.00 | 3.00 |
| Spray-dried blood meal | 1.75 | 2.00 |
| Antibiotic[c] | 1.00 | 1.00 |
| Monocalcium phosphate | 0.76 | 1.30 |
| Limestone | 0.48 | 0.79 |
| Zinc oxide | 0.38 | 0.25 |
| Vitamin premix[d] | 0.25 | 0.25 |
| Salt | 0.20 | 0.20 |
| L-Lysine HCl | 0.15 | 0.15 |
| Trace mineral premix | 0.15 | 0.15 |
| DL-methionine | 0.15 | 0.10 |
| Corn starch[e] | 0.10 | 0.10 |
| Total | 100.00 | 100.00 |

[a]Diets were formulated to contain 1.7% lysine, .48% methionine, .9% Ca, and .8% P.
[b]Diets were formulated to contain 1.4% lysine, . 39% methionine, .85% Ca, and .75% P.
[c]Provided 50 g/ton carbodox.
[d]Premix provided the following vitamins per pound of complete feed: vitamin A, 5000 IU; vitamin $D_3$, 750 IU; vitamin E, 20 IU; vitamin K, 2 mg; vitamin $B_{12}$, .02 mg; riboflavin, 4.5 mg; niacin, 25 mg; biotin, .10 mg; pyridoxine, 1.5 mg; and pantothenic acid, 0 mg.
[e]Pantothenic acid premix (d-Cal Pan) replaced corn starch to provide the three additional experimental treatments within each phase. Analyzed pantothenic acid concentrations fed 21.4, 49.7, 87.1, and 146.0 from d 0 to 14 after weaning and 12.6, 48.4, 96.8, and 127.0 ppm from d 14 to 28 after weaning for the control, 30, 60, and 120 ppm of added pantothenic acid diets, respectively.

**Table 2. Effects of Increasing Pantothenic Acid on Weaning Pig Growth Performance[a]**

| | Added Pantothenic Acid, ppm | | | | | P < | | |
|---|---|---|---|---|---|---|---|---|
| Item | 0 | 30 | 60 | 120 | SEM | Linear | Quadratic | Cubic |
| Day 0 to 7 | | | | | | | | |
| ADG, lb | .25 | .25 | .26 | .30 | .022 | .12 | .58 | .92 |
| ADFI, lb | .33 | .33 | .33 | .35 | .016 | .37 | .56 | .85 |
| F/G | 1.39 | 1.29 | 1.37 | 1.22 | .092 | .26 | .79 | .41 |
| Day 7 to 14 | | | | | | | | |
| ADG, lb | .64 | .61 | .64 | .68 | .022 | .09 | .23 | .39 |
| ADFI, lb | .66 | .63 | .67 | .72 | .021 | .03 | .27 | .31 |
| F/G | 1.04 | 1.05 | 1.07 | 1.06 | .032 | .55 | .73 | .87 |
| Day 0 to 14 | | | | | | | | |
| ADG, lb | .44 | .43 | .45 | .49 | .014 | .01 | .16 | .53 |
| ADFI, lb | .50 | .48 | .50 | .53 | .015 | .04 | .27 | .53 |
| F/G | 1.12 | 1.12 | 1.12 | 1.10 | .024 | .48 | .84 | .90 |
| Day 14 to 21 | | | | | | | | |
| ADG, lb | .56 | .60 | .65 | .62 | .022 | .05 | .03 | .54 |
| ADFI, lb | .91 | .91 | .95 | .94 | .020 | .16 | .56 | .37 |
| F/G | 1.68 | 1.53 | 1.47 | 1.54 | .050 | .10 | .01 | .92 |
| Day 21 to 28 | | | | | | | | |
| ADG, lb | 1.03 | 1.07 | 1.09 | 1.09 | .030 | .20 | .40 | .98 |
| ADFI, lb | 1.39 | 1.37 | 1.45 | 1.43 | .025 | .12 | .58 | .09 |
| F/G | 1.38 | 1.30 | 1.34 | 1.33 | .027 | .40 | .24 | .14 |
| Day 14 to 28 | | | | | | | | |
| ADG, lb | .80 | .84 | .87 | .85 | .022 | .07 | .10 | .75 |
| ADFI, lb | 1.15 | 1.14 | 1.20 | 1.19 | .019 | .08 | .50 | .11 |
| F/G | 1.48 | 1.38 | 1.39 | 1.41 | .025 | .16 | .02 | .29 |
| Day 0 to 28 | | | | | | | | |
| ADG, lb | .62 | .63 | .66 | .67 | .015 | .01 | .56 | .60 |
| ADFI, lb | .82 | .81 | .85 | .86 | .014 | .02 | .86 | .17 |
| F/G | 1.35 | 1.29 | 1.29 | 1.30 | .020 | .14 | .11 | .35 |

[a]A total of 275 weanling pigs (initially 8.8 lb ± 2.2 and 11 ± 2 d of age) with seven or eight pigs per pen and nine replications per treatment.

# INFLUENCE OF HIGH LEVELS OF ZINC FROM ZINC OXIDE, ZINC SULFATE, OR A ZINC AMINO ACID COMPLEX ON STARTER PIG PERFORMANCE [1]

*J. C. Woodworth, M. D. Tokach [2], S. S. Dritz [3], J. L. Nelssen, R. D. Goodband, P. R. O'Quinn, J. A. Loughmiller, S. A. Moser, and T. M. Fakler [4]*

## Summary

Three hundred and sixty early-weaned barrows were fed either a control diet; diets containing added Zn (100, 200, 300, 400, or 500 ppm) from zinc sulfate or a zinc amino acid complex (AvailaZn); or a diet containing 3,000 ppm of additional Zn from zinc oxide. All diets contained 165 ppm of Zn from zinc oxide from the trace mineral premix. Pigs fed 3,000 ppm of Zn from zinc oxide had maximum growth performance compared to those fed other diets, whereas those fed added zinc sulfate and AvailaZn showed intermediate results relative to the negative control and the 3,000 ppm of Zn from zinc oxide diet. These results support previous Kansas State University research showing maximum performance being achieved with additions of 3,000 ppm of Zn from zinc oxide. Further research is needed to evaluate the intermediate response to zinc sulfate and AvailaZn and determine whether the benefits in ADG and F/G were due to a growth promotion response or whether the starter pig has a higher Zn requirement than met by the negative control (165 ppm Zn from zinc oxide).

(Key Words: Early-Weaned Pigs, Growth, Zinc)

## Introduction

Several experiments have demonstrated the benefits in daily gain and feed efficiency from adding high levels of Zn (3,000 ppm) from zinc oxide to starter diets. The same growth response with zinc sulfate has not been observed consistently. One study found no benefit in daily gain from adding 3,000 ppm of Zn from zinc methionine or zinc sulfate to the starter diet, but 3,000 ppm of Zn from zinc oxide improved pig performance. The difference in bioavailability may have caused the plasma Zn levels to become too high for pigs fed the zinc sulfate and methionine sources compared to zinc oxide. Recent research has suggested that a lower level of Zn (250 ppm) from a zinc amino acid complex (Zn Met or AvailaZn) will improve performance in a similar manner as high levels of zinc oxide (2,000 ppm). The trials finding this response had control diets containing 250 ppm of Zn from zinc sulfate from d 0 to 13 after weaning and 160 ppm of Zn from zinc sulfate from d 13 to 35. A question remains whether the benefits to the zinc amino acid complex were due to the 250 ppm of Zn from the complex or to the total Zn level of 410 to 500 ppm from zinc sulfate plus the complex.

[1] Appreciation is expressed to Zinpro Corporation, Eden Prairie, MN for partial financial support for this experiment. The authors thank Newsham Hybrids, Colorado Springs, CO, for supplying the pigs. The authors also thank Colin Bradley of the London Health Sciences Centre, London, Ontario, Canada for conducting the serum Zn analysis.

[2]Northeast Area Extension Office, Manhattan, KS.

[3]Food Animal Health and Management Center.

[4]Zinpro Corporation, Eden Prairie, MN.

## Procedures

A total of 360 weanling barrows (initially 9.30 lb and 12 ± 2 d of age; Newsham Hybrids) was used in a 20-d growth assay. Pigs were blocked by initial weight and allotted randomly to each of 12 dietary treatments. Each treatment had five pigs per pen and six replications (pens) per treatment.

The 12 experimental diets consisted of a negative control diet containing 165 ppm of Zn from zinc oxide in the trace mineral premix; five diets containing added zinc sulfate (100, 200, 300, 400, and 500 ppm of Zn); five diets containing added zinc amino acid complex (100, 200, 300, 400, and 500 ppm of Zn); and a positive control diet containing 3,000 ppm of Zn from zinc oxide. The zinc amino acid complex used in this trial was AvailaZn, which is produced by the ZinPro Corporation.

All experimental diets were fed in meal form. Diets fed from d 0 to 5 after weaning were formulated to contain 1.70% lysine, .48% methionine, .90% Ca, and .80% P (Table 1). Diets fed from d 5 to 10 were formulated to contain 1.55% lysine, .44% methionine, .90% Ca, and .80% P. Diets fed from d 10 to 20 were formulated to contain 1.40% lysine, .39% methionine, .85% Ca, and .75% P. The zinc sulfate, AvailaZn, or zinc oxide replaced cornstarch in the control diet to provide the additional Zn. Pigs were fed the same experimental Zn concentrations throughout the 20 d study.

Pigs were weighed and feed disappearance was determined on d 0, 5, 10, and 20 to calculate ADG, ADFI, and F/G. Feed samples were collected and analyzed to determine Zn concentration. Two pigs per pen were selected randomly and bled on d 20 to determine serum Zn concentrations. Serum Zn values (Table 3) represent the treatment means of pooled samples from the two pigs per pen.

Data were analyzed as a randomized complete block design in a 2 × 5 factorial with two control diets. Linear and quadratic values were evaluated for zinc sulfate and AvailaZn including the negative control. Data were analyzed for main effects (Zn source and level) and two-way interactions. Contrast statements were used to investigate the mean differences between pigs fed the two control diets and the other diets.

## Results and Discussion

From d 0 to 5 and 5 to 10, no differences ($P>.05$, Tables 3 and 4) were observed among treatments. Pigs fed 100 ppm of Zn from AvailaZn had the highest numerical ADG and ADFI (.28 lb and .34 lb respectively, Table 2) but were not different ($P>.10$) from pigs in other treatments.

From d 10 to 20, ADG was highest ($P<.02$) for pigs fed the positive control diet containing 3,000 ppm of Zn from zinc oxide and lowest ($P<.01$) for pigs fed the negative control diet, whereas pigs fed zinc sulfate or AvailaZn had intermediate responses. Average daily gain increased then decreased for pigs fed AvailaZn (quadratic, $P<.05$), with pigs fed 200 ppm of added Zn having the greatest improvement. Increasing zinc sulfate had no effect ($P>.05$) on growth performance, but pigs fed the diet containing 100 ppm of added Zn had numerically the highest ADG. Source or level of Zn from d 10 to 20 did not affect average daily feed intake. Feed efficiency was improved ($P<.01$) for pigs fed the diet containing 3,000 ppm of Zn from zinc oxide compared to the other treatments. Feed efficiency worsened (linear, $P<.02$) for pigs fed diets containing increasing zinc sulfate, with the best F/G observed for pigs fed 100 ppm of added Zn. Pigs fed diets containing increasing AvailaZn had decreasing then increasing (quadratic, $P<.02$) F/G, with the best F/G observed in pigs fed 300 ppm of added Zn.

Cumulative results (d 0 to 20) resembled those for d 10 to 20. Average daily gain was greater ($P<.05$) for pigs fed the positive control diet compared to diets containing zinc sulfate or the negative control and tended to be higher ($P<.07$) compared to pigs fed diets containing AvailaZn. Average daily feed intake was not affected by Zn level or source. Feed efficiency was best ($P<.04$) for

pigs fed the positive control diet compared to other sources. Pigs fed the diets containing added AvailaZn had decreasing then increasing (quadratic, P<.05) F/G, with pigs fed the diet containing 300 ppm of added Zn having the best F/G.

Analyzed dietary Zn concentrations (Table 2) generally increased with increasing Zn supplementation. However, some analyzed Zn concentrations showed considerable differences from calculated values. These differences could be due to the 20% variation permitted for Zn analysis.

Serum Zn levels were highest (P<.0001) for pigs fed the positive control (Table 3 and 4). No statistical difference (P>.05) occurred between the other treatments.

In conclusion, our results support previous research at Kansas State University showing maximum growth performance being achieved by including 3,000 ppm of Zn from zinc oxide to the starter diet. Pigs fed zinc sulfate and AvailaZn had intermediate performance, with improved ADG and F/G compared to the pigs fed the negative control but lower ADG than pigs fed the positive control with 3,000 ppm of Zn from zinc oxide. Further research is needed to evaluate the intermediate response to zinc sulfate and AvailaZn and determine whether the benefits in ADG and F/G were due to a growth promotion response or whether the starter pig has a higher Zn requirement than met by the negative control. Further research also is needed to determine whether a higher level of bioavailable Zn from an inorganic source is required to elicit the full response observed with organic Zn sources.

**Table 1. Diet Compositions (As-Fed Basis)**

| Ingredient, % | Day 0 to 5[a] | Day 5 to 10[b] | Day 10 to 20[c] |
|---|---|---|---|
| Corn | 38.69 | 45.61 | 51.95 |
| Dried whey | 25.00 | 20.00 | 10.00 |
| Soybean meal (46.5% CP) | 12.18 | 21.30 | 28.50 |
| Spray-dried animal plasma | 6.75 | 2.50 | - |
| Select menhaden fish meal | 6.00 | 2.50 | - |
| Lactose | 5.00 | - | - |
| Soy oil | 2.00 | 2.00 | 3.00 |
| Spray-dried blood meal | 1.75 | 2.50 | 2.50 |
| Monocalcium phosphate | .69 | 1.26 | 1.59 |
| Limestone | .50 | .76 | .99 |
| Cornstarch[d] | .50 | .50 | .50 |
| Salt | .25 | .30 | .30 |
| Vitamin premix | .25 | .25 | .25 |
| L-Lysine HCL | .15 | .15 | .15 |
| Trace mineral premix[e] | .15 | .15 | .15 |
| DL-Methionine | .12 | .15 | .10 |
| Total | 100.00 | 100.00 | 100.00 |

[a]Diets were formulated to contain 1.70% lysine, .48% methionine, .90% Ca, and .80% P and were fed from d 0 to 5 after weaning.
[b]Diets were formulated to contain 1.55% lysine, .44% methionine, .90% Ca, and .80% P and were fed from d 5 to 10.
[c]Diets were formulated to contain 1.40% lysine, .39% methionine, .85% Ca, and .75% P and were fed from d 10 to 20.
[d]Zinc sulfate or AvailaZn replaced corn starch to provide an additional 100, 200, 300, 400, or 500 ppm of Zn. Zinc oxide replaced cornstarch to provide an additional 3,000 ppm of Zn.
[e]Provided per ton of complete feed: 36 g Mn; 150 g Fe; 150 g Zn from ZnO; 15 g Cu; 270 mg I; and 270 mg Se.

**Table 2. Analyzed Zinc Concentrations (ppm) of Formulated Diets[a]**

| | | Zinc from Zinc Sulfate (ppm) | | | | | Zinc from AvailaZn (ppm) | | | | | Zinc from ZnO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Control[b] | 100 | 200 | 300 | 400 | 500 | 100 | 200 | 300 | 400 | 500 | 3,000 ppm |
| Day 0 to 5 | | | | | | | | | | | | |
| Zn | 172 | 312 | 339 | 582 | 559 | 809 | 326 | 362 | 466 | 703 | 739 | 3,627 |
| Day 5 to 10 | | | | | | | | | | | | |
| Zn | 204 | 324 | 407 | 436 | 505 | 773 | 335 | 416 | 559 | 607 | 774 | 3,475 |
| Day 10 to 20 | | | | | | | | | | | | |
| Zn | 255 | 298 | 337 | 461 | 586 | 660 | 318 | 425 | 412 | 629 | 819 | 3,150 |

[a]Values (as-fed basis) represent analysis of one sample per diet for each time period. [b]All diets contained an additional 165 ppm of Zn from zinc oxide as part of the trace mineral premix.

**Table 3. Influence of High Levels of Zinc from Zinc Oxide, Zinc Sulfate, or AvailaZn on Starter Pig Performance[a]**

| | | Zinc from Zinc Sulfate (ppm) | | | | | Zinc from AvailaZn (ppm) | | | | | Zinc from Zinc Oxide |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Control[b] | 100 | 200 | 300 | 400 | 500 | 100 | 200 | 300 | 400 | 500 | 3,000 ppm |
| Day 0 to 5 | | | | | | | | | | | | |
| ADG, lb | 0.21 | 0.21 | 0.22 | 0.24 | 0.18 | 0.21 | 0.28 | 0.22 | 0.19 | 0.20 | 0.24 | 0.20 |
| ADFI, lb | 0.23 | 0.24 | 0.26 | 0.25 | 0.22 | 0.26 | 0.34 | 0.25 | 0.24 | 0.23 | 0.26 | 0.27 |
| F/G | 1.14 | 1.14 | 1.20 | 1.04 | 1.19 | 1.30 | 1.20 | 1.18 | 1.32 | 1.15 | 1.10 | 1.39 |
| Day 5 to 10 | | | | | | | | | | | | |
| ADG, lb | 0.36 | 0.36 | 0.36 | 0.30 | 0.37 | 0.38 | 0.37 | 0.36 | 0.41 | 0.36 | 0.39 | 0.39 |
| ADFI, lb | 0.56 | 0.55 | 0.60 | 0.56 | 0.56 | 0.63 | 0.63 | 0.59 | 0.58 | 0.54 | 0.59 | 0.57 |
| F/G | 1.52 | 1.52 | 1.67 | 1.89 | 1.52 | 1.69 | 1.72 | 1.67 | 1.41 | 1.56 | 1.52 | 1.45 |
| Day 0 to 10 | | | | | | | | | | | | |
| ADG, lb | 0.28 | 0.28 | 0.29 | 0.27 | 0.28 | 0.29 | 0.32 | 0.29 | 0.30 | 0.28 | 0.32 | 0.30 |
| ADFI, lb | 0.40 | 0.39 | 0.43 | 0.40 | 0.39 | 0.45 | 0.48 | 0.42 | 0.41 | 0.39 | 0.43 | 0.42 |
| F/G | 1.39 | 1.39 | 1.47 | 1.47 | 1.41 | 1.54 | 1.49 | 1.47 | 1.37 | 1.39 | 1.35 | 1.43 |
| Day 10 to 20 | | | | | | | | | | | | |
| ADG, lb | 0.70 | 0.83 | 0.78 | 0.78 | 0.80 | 0.78 | 0.77 | 0.81 | 0.79 | 0.78 | 0.75 | 0.88 |
| ADFI, lb | 1.09 | 1.08 | 1.10 | 1.08 | 1.05 | 1.11 | 1.13 | 1.13 | 1.05 | 1.04 | 1.10 | 1.16 |
| F/G | 1.56 | 1.30 | 1.41 | 1.39 | 1.32 | 1.41 | 1.45 | 1.39 | 1.32 | 1.33 | 1.47 | 1.32 |
| Day 0 to 20 | | | | | | | | | | | | |
| ADG, lb | 0.49 | 0.56 | 0.53 | 0.52 | 0.54 | 0.53 | 0.55 | 0.55 | 0.55 | 0.53 | 0.53 | 0.59 |
| ADFI, lb | 0.74 | 0.74 | 0.76 | 0.74 | 0.72 | 0.78 | 0.81 | 0.77 | 0.73 | 0.71 | 0.76 | 0.79 |
| F/G | 1.49 | 1.33 | 1.43 | 1.43 | 1.33 | 1.45 | 1.47 | 1.41 | 1.33 | 1.35 | 1.43 | 1.35 |
| Day 20 Serum[c] | | | | | | | | | | | | |
| Zn, mg/L | 1.13 | 1.11 | 1.10 | 1.09 | 1.03 | 1.11 | 1.10 | 0.99 | 1.07 | 1.09 | 1.14 | 2.46 |

[a]A total of 360 weanling pigs (initially 9.30 lb and 12 d of age), five pigs per pen and six pens per treatment. [b]All diets contained an additional 165 ppm of Zn from zinc oxide as part of the trace mineral premix. [c]Values represent treatment means of pooled samples from two pigs per pen.

**Table 4. Statistical Analysis of Mean Values (P <)**

| | Zn Sulfate | | AvailaZn | | Interaction | | | | Contrasts, (P <)[a] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Linear | Quad. | Linear | Quad. | Source | Level | Source × Level | CV | 1 | 2 | 3 | 4 | 5 |
| Day 0 to 5 | | | | | | | | | | | | | |
| ADG | .87 | .27 | .77 | .59 | .47 | .41 | .25 | 29.1 | .86 | .50 | .37 | .81 | .64 |
| ADFI | .72 | .26 | .31 | .67 | .12 | .06 | .08 | 19.8 | .17 | .17 | .69 | .64 | .19 |
| F/G | .74 | .66 | .83 | .33 | .56 | .97 | .18 | 24.6 | .21 | .69 | .22 | .95 | .12 |
| Day 5 to 10 | | | | | | | | | | | | | |
| ADG | .63 | .49 | .79 | .91 | .42 | .96 | .45 | 27.5 | .58 | .75 | .69 | .86 | .37 |
| ADFI | .96 | .64 | .76 | .80 | .77 | .63 | .56 | 16.8 | .79 | .55 | .80 | .68 | .94 |
| F/G | .44 | .22 | .66 | .82 | .46 | .97 | .10 | 21.5 | .70 | .72 | .39 | .44 | .21 |
| Day 0 to 10 | | | | | | | | | | | | | |
| ADG | .65 | .84 | .92 | .89 | .29 | .66 | .84 | 20.4 | .70 | .53 | .89 | .98 | .61 |
| ADFI | .90 | .41 | .57 | .73 | .40 | .27 | .23 | 15.4 | .46 | .32 | .97 | .62 | .65 |
| F/G | .61 | .48 | .54 | .49 | .53 | .94 | .38 | 14.6 | .70 | .68 | .94 | .45 | .80 |
| Day 10 to 20 | | | | | | | | | | | | | |
| ADG | .15 | .15 | .40 | .05 | .59 | .86 | .66 | 10.3 | .0003 | .03 | .008 | .01 | .02 |
| ADFI | .57 | .70 | .48 | .85 | .95 | .45 | .87 | 10.7 | .29 | .91 | .14 | .87 | .13 |
| F/G | .02 | .22 | .11 | .02 | .46 | .22 | .26 | 8.9 | .003 | .01 | .20 | .003 | .38 |
| Day 0 to 20 | | | | | | | | | | | | | |
| ADG | .39 | .24 | .51 | .19 | .87 | .89 | .92 | 10.9 | .006 | .07 | .07 | .09 | .05 |
| ADFI | .67 | .56 | .48 | .99 | .71 | .32 | .67 | 11.1 | .31 | .76 | .31 | .94 | .21 |
| F/G | .12 | .56 | .09 | .05 | .81 | .24 | .08 | 7.5 | .02 | .04 | .30 | .03 | .36 |
| Day 20 Serum | | | | | | | | | | | | | |
| Zn | .26 | .74 | .90 | .07 | .77 | .58 | .65 | 16.7 | .0001 | .56 | .0001 | .64 | .0001 |

[a]Contrasts were 1) neg control vs 3,000 ppm of Zn (ZnO), 2) neg control vs AvailaZn, 3) 3,000 ppm of Zn (ZnO) vs AvailaZn, 4) neg control vs Zn sulfate, and 5) 3,000 ppm of Zn (ZnO) vs Zn sulfate.

# INFLUENCE OF ADDED ZINC FROM ZINC OXIDE OR A ZINC AMINO ACID COMPLEX ON STARTER PIG GROWTH PERFORMANCE [1]

***J. C. Woodworth, M. D. Tokach [2], J. L. Nelssen, R. D. Goodband, P. R. O'Quinn, S. A. Moser, R. E. Musser, and T. M. Fakler [3]***

## Summary

A total of 360 pigs (initially 11.5 lb and 16 d of age) was fed a negative control diet containing no added Zn; one of six diets containing 165 ppm Zn from zinc oxide from the trace mineral premix and added AvailaZn (0, 100, 200, 300, 400, or 500 ppm of Zn); or a positive control diet containing 3,165 ppm added Zn from zinc oxide. Pigs fed the positive control diet had higher (P<.02) ADG and ADFI compared to pigs in all other treatments for the duration of the trial. Pigs fed diets containing AvailaZn had numerically higher ADG and ADFI than pigs fed diets containing no added Zn for the entire trial. These results are similar to previous research showing maximum growth performance exhibited by pigs fed high levels (3,000 ppm) of Zn from zinc oxide.

(Key Words: Early-Weaned Pigs, Growth, Zinc.)

## Introduction

A previous study at Kansas State University compared the effects of added Zn from zinc sulfate or a zinc amino acid complex (AvailaZn) to a diet containing no additional Zn and a diet containing 3,000 ppm Zn from zinc oxide. All diets contained 165 ppm Zn (zinc oxide) from the trace mineral premix. Although pigs fed the zinc sulfate and AvailaZn diets had lower ADG and ADFI compared to pigs fed high levels of zinc oxide, all pigs showed improvements in growth performance over those fed the diets containing no additional Zn. Previous research at Kansas State University and other universities, has also shown this growth promotional effect of adding 3,000 ppm Zn from zinc oxide. However, adding high levels of Zn from other inorganic Zn sources has not resulted in a growth promotional response. Other research has shown that adding lower levels of Zn (250 ppm) from an organic zinc amino acid complex to diets containing 250 ppm Zn from zinc sulfate improved performance in a similar manner as high levels of zinc oxide. Many of the trials showing the similar response between organic sources and zinc oxide used only 2,000 ppm Zn from zinc oxide as the positive control, which does not produce the growth promotional response of 3,000 ppm Zn. The objective of this trial was to determine if pigs fed diets containing Zn from a zinc amino acid complex (AvailaZn) would show similar growth responses compared to pigs fed diets containing 3,000 ppm of Zn from zinc oxide.

---

[1]Appreciation is expressed to Zinpro Corporation, Eden Prairie, MN for partial financial support and supplying the AvaliaZn used in this experiment. The authors thank Henry's Ltd., Longford, KS for supplying the pigs. The authors also thank Colin Bradley of the London Health Sciences Centre, London, Ontario, Canada for conducting the serum Zn analysis.

[2]Northeast Area Extension Office, Manhattan, KS.

[3]Zinpro Corporation, Eden Prairie, MN.

## Procedures

A total of 360 weanling pigs (initially 11.5 lb and 16 d of age; PIC L-C22 barrows) was used in a 34-d growth assay to determine the influence of added Zn from zinc oxide or a zinc amino acid complex (AvailaZn) on weanling pig growth performance. Pigs were blocked by initial weight and allotted randomly to each of eight dietary treatments. Each treatment had five pigs per pen and nine replications (pens) per treatment.

All experimental diets were fed in meal form. Diets fed from d 0 to 5 after weaning were formulated to contain 1.70% lysine, .48% methionine, .90% Ca, and .80% P (Table 1). Diets fed from d 5 to 10 were formulated to contain 1.55% lysine, .44% methionine, .90% Ca, and .80% P. Diets fed from d 10 to 20 were formulated to contain 1.40% lysine, .39% methionine, .85% Ca, and .75% P. Diets fed from d 20 to 34 were formulated to contain 1.30% lysine, .36% methionine, .75% Ca, and .70% P. The eight experimental diets consisted of a negative control diet containing no added Zn; six diets containing 165 ppm of Zn from zinc oxide from the trace mineral premix and one of six levels of added Zn from AvailaZn (0, 100, 200, 300, 400, or 500 ppm Zn); and a positive control diet containing 165 ppm of Zn from the trace mineral premix plus 3,000 ppm of added Zn from zinc oxide. Pigs were fed the same experimental Zn concentrations throughout the 34 d study. Zinc oxide and AvailaZn replaced cornstarch in the negative control diet to form the experimental treatments.

Pigs were housed in the Kansas State University SEW buildings for the entire trial. Each pen was 4 × 4 ft in area and contained one nipple waterer and one five-hole self-feeder to provide ad libitum access to feed and water.

Pigs were weighed and feed disappearance was determined on d 0, 5, 10, 20, and 34 to calculate ADG, ADFI, and F/G. Diet samples were collected from each phase and analyzed to determine dietary zinc concentrations. Two pigs per pen were selected randomly and bled on days 20 and 34 to determine serum Zn levels. Samples were centrifuged, and the serum from the two pigs in each pen was pooled for analysis.

Data were analyzed as a randomized complete block design with pen as the experimental unit. Linear and quadratic polynomials were used to test the effects of increasing AvailaZn. Contrast statements were used to investigate the mean differences between the positive and negative controls and the mean of the diets containing AvailaZn. Significance was determined using $\alpha = .05$.

## Results and Discussion

From d 0 to 10, ADG was highest ($P<.03$; Table 3) for pigs fed diets containing 3,000 ppm of Zn from zinc oxide compared to pigs fed any other diet. Pigs fed diets containing 3,000 ppm of Zn from zinc oxide had higher ($P<.03$) ADFI compared to pigs fed diets containing no added Zn but similar ($P> .10$) ADFI compared to the mean of diets containing AvailaZn. Feed:gain ratio was not different ($P>.10$) across experimental treatments. From d 0 to 10, pigs fed diets containing AvailaZn had ADG, ADFI, and F/G similar ($P>.10$) to the negative control. Increasing AvailaZn had no effect ($P>.10$) on ADG, ADFI, or F/G.

From d 10 to 20, pigs fed diets containing 3,000 ppm of Zn from zinc oxide had the highest ($P<.002$) ADG and ADFI compared to all other treatments. Pigs fed AvailaZn had ADG and ADFI similar ($P>.10$) to those of pigs fed diets containing no added Zn. Pigs fed AvailaZn had improved ($P<.02$) F/G compared to the positive and negative controls. This improved feed efficiency did not increase ADG from d 10 to 20 because of the lower feed intakes of pigs fed AvailaZn. Increasing levels of AvailaZn from 100 to 500 ppm of added Zn did not affect ($P>.10$) ADG, ADFI, or F/G.

From d 20 to 34, pigs fed 3,000 ppm of Zn from zinc oxide tended to have increased ($P<.09$) ADG compared to the negative control but did not differ ($P>10$) from pigs fed diets containing AvailaZn. Average daily

feed intake was maximized (P<.007) for pigs fed diets containing 3,000 ppm of Zn from zinc oxide compared to all other treatments. The higher feed intake but similar ADG of pigs fed 3,000 ppm of Zn from zinc oxide contributed to the higher (P<.05) F/G of the positive control compared to all other treatments. Pigs fed diets containing AvailaZn had improved (P<.003) F/G compared to the positive control diet, but F/G was not different (P>.10) compared to the diet containing no added Zn. Increasing AvailaZn supplementation tended to decrease (linear, P<.10) ADFI and improve F/G of pigs fed the highest level of added AvailaZn.

Overall from d 0 to 34, pigs fed diets containing 3,000 ppm of Zn from zinc oxide had the highest (P<.02) ADG and ADFI compared to pigs fed any other diet. Average daily gain and ADFI were similar (P>.10) between the negative control and diets containing AvailaZn. Feed to gain ratio was not different (P>.10) among the negative control diet and diets containing AvailaZn or the positive control diet, whereas diets containing AvailaZn had improved (P<.004) F/G compared to diets containing 3,000 ppm of Zn from zinc oxide. Similar to d 20 to 34, increasing AvailaZn decreased (linear, P<.05) F/G primarily because of lower feed intakes exhibited by pigs fed the highest level of AvailaZn.

Analyzed Zn concentrations of the diets (Table 2) generally increased with increasing Zn additions. However, some analyzed concentrations showed considerable variation from calculated values. These differences could be due to the 20% variation permitted for Zn analysis.

Pigs fed diets containing 3,000 ppm of Zn from zinc oxide had the highest (P<.008) blood serum Zn concentrations compared to all other treatments on d 20 and d 34. Pigs fed diets containing AvailaZn had higher (P<.008) serum Zn concentrations than pigs fed the negative control diet containing no additional Zn. Increasing levels of added Zn from AvailaZn had no effect (P>.10) on serum Zn concentration. The heparin tubes used to collect the blood also were analyzed for Zn concentration and found to contain .05 mg/L Zn. Therefore, the total analyzed serum Zn values were adjusted by subtracting .05 mg/L.

In conclusion, pigs fed diets containing 3,000 ppm Zn from zinc oxide exhibited the best ADG and ADFI compared to pigs fed all other treatments. These results agree with past research conducted at Kansas State University and other universities showing the benefits of increased growth performance from pharmacological levels of Zn from zinc oxide. The results of this trial agree with our first trial showing reduced growth performance of pigs fed AvailaZn compared to pigs fed diets containing growth-promotional levels of Zn from zinc oxide. Contrary to research conducted at other universities, pigs fed diets containing Zn from the zinc amino acid complex did not exhibit growth performance similar to pigs fed diets containing high levels of Zn from zinc oxide. These results suggest that 3,000 ppm Zn from zinc oxide should be added to the diets of weanling pigs.

**Table 1. Diet Compositions (As-Fed Basis)**

| Ingredient, % | Day 0 to 5[a] | Day 5 to 10[b] | Day 10 to 20[c] | Day 20 to 34[d] |
|---|---|---|---|---|
| Corn | 38.69 | 45.66 | 51.95 | 58.72 |
| Dried whey | 25.00 | 20.00 | 10.00 | - |
| Soybean meal (46.5% CP) | 12.18 | 21.30 | 28.50 | 34.39 |
| Spray-dried animal plasma | 6.75 | 2.50 | - | - |
| Select menhaden fish meal | 6.00 | 2.50 | - | - |
| Lactose | 5.00 | - | - | - |
| Soy oil | 2.00 | 2.00 | 3.00 | 3.00 |
| Spray-dried blood meal | 1.75 | 2.50 | 2.50 | - |
| Monocalcium phosphate | .70 | 1.27 | 1.60 | 1.48 |
| Limestone | .51 | .77 | 1.0 | .97 |
| Cornstarch[e] | .50 | .50 | .50 | .50 |
| Salt | .25 | .30 | .30 | .35 |
| Vitamin premix | .25 | .25 | .25 | .25 |
| L-Lysine HCL | .15 | .15 | .15 | .15 |
| Trace mineral premix[f] | .15 | .15 | .15 | .15 |
| DL-Methionine | .12 | .15 | .10 | .04 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 |

[a]Diets were formulated to contain 1.70% lysine, .48% methionine, .90% Ca, and .80% P and were fed from d 0 to 5 after weaning.
[b]Diets were formulated to contain 1.55% lysine, .44% methionine, .90% Ca, and .80% P and were fed from d 5 to 10.
[c]Diets were formulated to contain 1.40% lysine, .39% methionine, .85% Ca, and .75% P and were fed from d 10 to 20.
[d]Diets were formulated to contain 1.30% lysine, .36% methionine, .75% Ca, and .70% P and were fed from d 20 to 34.
[e]Zinc sources replaced cornstarch to provide the experimental treatments.
[f]Provided per ton of complete feed: 36 g Mn; 150 g Fe; 15 g Cu; 270 mg I; and 270 mg Se.

**Table 2. Analyzed Zinc Concentrations (ppm) of Formulated Diets[a]**

| | Added Zinc (ppm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| AvailaZn | 0 | 0 | 100 | 200 | 300 | 400 | 500 | 0 |
| Item ZnO | 0 | 165 | 165 | 165 | 165 | 165 | 165 | 3,165 |
| Day 0 to 5 | | | | | | | | |
| Zn | 55 | 202 | 309 | 395 | 512 | 577 | 708 | 2,886 |
| Day 5 to 10 | | | | | | | | |
| Zn | 105 | 223 | 342 | 346 | 485 | 585 | 717 | 3,507 |
| Day 10 to 20 | | | | | | | | |
| Zn | 102 | 198 | 238 | 348 | 457 | 574 | 658 | 2,872 |
| Day 20 to 34 | | | | | | | | |
| Zn | 108 | 162 | 287 | 325 | 515 | 593 | 621 | 2,358 |

[a]Values (as-fed basis) represent one sample per diet for each time period.

**Table 3. Influence of Added Zinc from Zinc Oxide or a Zinc Amino Acid Complex on Starter Pig Growth Performance[a]**

| | | Added Zinc (ppm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AvailaZn | 0 | 0 | 100 | 200 | 300 | 400 | 500 | 0 | | Contrasts (P <)[b] | |
| Item | ZnO | 0 | 165 | 165 | 165 | 165 | 165 | 165 | 3,165 | CV | 1 | 2 | 3 |
| Day 0 to 10 | | | | | | | | | | | | | |
| ADG, lb | | .27 | .28 | .28 | .29 | .29 | .30 | .27 | .35 | 24.16 | .03 | .68 | .02 |
| ADFI, lb | | .35 | .39 | .38 | .42 | .39 | .41 | .36 | .43 | 19.56 | .03 | .16 | .12 |
| F/G | | 1.28 | 1.36 | 1.34 | 1.51 | 1.33 | 1.39 | 1.44 | 1.28 | 16.35 | .98 | .16 | .17 |
| Day 10 to 20 | | | | | | | | | | | | | |
| ADG, lb | | .64 | .64 | .68 | .68 | .65 | .66 | .68 | .78 | 13.33 | .002 | .47 | .001 |
| ADFI, lb | | .89 | .83 | .88 | .89 | .85 | .89 | .84 | 1.08 | 12.53 | .001 | .45 | .001 |
| F/G | | 1.40 | 1.31 | 1.31 | 1.30 | 1.31 | 1.35 | 1.24 | 1.38 | 7.12 | .76 | .007 | .02 |
| Day 20 to 34 | | | | | | | | | | | | | |
| ADG, lb | | 1.16 | 1.20 | 1.21 | 1.22 | 1.25 | 1.20 | 1.17 | 1.23 | 7.34 | .09 | .14 | .42 |
| ADFI, lb[c] | | 1.69 | 1.77 | 1.83 | 1.73 | 1.76 | 1.74 | 1.68 | 1.89 | 7.57 | .004 | .23 | .007 |
| F/G[c] | | 1.46 | 1.47 | 1.51 | 1.42 | 1.41 | 1.45 | 1.43 | 1.53 | 4.72 | .05 | .58 | .003 |
| Day 0 to 34 | | | | | | | | | | | | | |
| ADG, lb | | .75 | .77 | .79 | .80 | .79 | .78 | .76 | .84 | 8.42 | .004 | .17 | .02 |
| ADFI, lb | | 1.06 | 1.10 | 1.13 | 1.12 | 1.09 | 1.10 | 1.05 | 1.22 | 8.13 | .001 | .33 | .001 |
| F/G[d] | | 1.42 | 1.42 | 1.43 | 1.40 | 1.37 | 1.41 | 1.37 | 1.46 | 3.40 | .16 | .26 | .004 |
| Day 20 Serum[e] | | | | | | | | | | | | | |
| Zn, mg/L | | .27 | .69 | .73 | .81 | .76 | .71 | .71 | 1.91 | 25.42 | .001 | .001 | .001 |
| Day 34 Serum[e] | | | | | | | | | | | | | |
| Zn, mg/L | | .54 | 1.13 | .94 | 1.02 | .96 | .96 | 1.00 | 2.24 | 33.01 | .001 | .008 | .001 |

[a]A total of 360 pigs (initially 11.5 lb and 16 d of age), five pigs per pen and nine replications per treatment.
[b]Contrasts were: 1) 0 ppm added Zn vs. 3,165 ppm added Zn (Zinc oxide), 2) 0 ppm added Zn vs. AvailaZn, and 3) 3,165 ppm added Zn (Zinc oxide) vs. AvailaZn.
[c]Linear AvailaZn (P<.10).
[d]Linear AvailaZn (P<.05).
[e]Values represent treatment means of pooled samples from two pigs per pen.

# INFLUENCE OF ADDED ZINC FROM ZINC OXIDE ON STARTER PIG PERFORMANCE [1]

*J. C. Woodworth, M. D. Tokach [2], S. S. Dritz [3], J. L. Nelssen, R. D. Goodband, P. R. O'Quinn, and T. M. Fakler [4]*

## Summary

Three hundred and sixty early-weaned barrows were fed diets containing increasing levels of added Zn from zinc oxide (0, 50, 100, 200, 400, 800, 1,600, 2,400, and 3,200 ppm). From d 11 to 21, growth performance improved with up to 100 ppm of added Zn but was not improved further until pigs were fed 3,200 ppm of added Zn. From d 21 to 36, pigs fed 100 ppm of Zn had the best growth performance. These results suggest that a pig's basal Zn requirement is met with 100 ppm of added Zn from zinc oxide, but adding 3,200 ppm Zn in early starter diets results in further growth promotion. For these reasons, 3,200 ppm Zn from zinc oxide should be added to diets fed from weaning (8 to 10 lb) until 15 lb and a reduced amount in subsequent diets.

(Key Words: Early-Weaned Pigs, Growth, Zinc.)

## Introduction

Previous research at Kansas State University compared the effects of added Zn from zinc sulfate or a zinc amino acid complex (AvailaZn) to a diet containing no additional Zn and a diet containing 3,000 ppm of Zn from zinc oxide. All diets contained 165 ppm Zn (zinc oxide) from the trace mineral premix. Although pigs fed the zinc sulfate and AvailaZn diets had numerically lower ADG and ADFI compared to pigs fed the diet containing 3,000 ppm of Zn, all pigs showed improvements in growth performance over those fed the diet containing 165 ppm of Zn from zinc oxide. These responses indicated that the pig's requirement for Zn may be higher than previously estimated and that even higher concentrations of added Zn above this requirement also may have a growth promotional effect.

The results of this trial lead us to question the basal Zn requirement of the young pig and whether the response to high levels of zinc oxide is a true growth promotional effect or simply a measure of meeting the pig's Zn requirement. Therefore, we chose to titrate a wide range of dietary Zn concentrations to determine the effect on pig growth performance. Zinc oxide was chosen as the Zn source because of its consistent effect of growth promotion.

## Procedures

A total of 360 weanling barrows (initially 8.6 lb and 12 ± 2 d of age; Newsham Hybrids) was used in a 36-d growth trial. Pigs were blocked by initial weight and

[1]Appreciation is expressed to Zinpro Corporation, Eden Prairie, MN for partial financial support for this experiment, and to Newsham Hybrids, Colorado Springs, CO for supplying the pigs for this experiment. The authors also thank Colin Bradley of the London Health Sciences Centre, London, Ontario, Canada for conducting the serum Zn analysis.

[2]Northeast Area Extension Office, Manhattan, KS.

[3]Food Animal Health and Management Center.

[4]Zinpro Corporation, Eden Prairie, MN.

allotted randomly to each of nine dietary treatments. Each treatment had five pigs per pen and eight replications (pens) per treatment.

All experimental diets were fed in meal form. Diets fed from d 0 to 5 after weaning were formulated to contain 1.70% lysine, .48% methionine, .90% Ca, and .80% P (Table 1). Diets fed from d 5 to 11 were formulated to contain 1.55% lysine, .44% methionine, .90% Ca, and .80% P. Diets fed from d 11 to 21 were formulated to contain 1.40% lysine, .39% methionine, .85% Ca, and .75% P. Diets fed from d 21 to 36 were formulated to contain 1.30% lysine, .36% methionine, .75% Ca, and .70% P. Zinc oxide replaced cornstarch in the control to form the experimental treatments. The nine dietary treatments consisted of a control diet containing no added Zn or the control diet with increasing levels of Zn from zinc oxide (50, 100, 200, 400, 800, 1,600, 2,400, and 3,200 ppm of Zn). The trace mineral premix had no added Zn. The zinc oxide used in this experiment was analyzed, and Zn concentration was determined to be 72%. Pigs were fed the same experimental Zn concentrations throughout the 36-d study.

Pigs were weighed and feed disappearance was determined on d 0, 5, 11, 21, and 36 to calculate ADG, ADFI, and F/G. Feed samples were collected and analyzed for Zn concentration. Two pigs per pen were selected randomly and bled on d 21 and 36 to determine serum Zn levels. Serum Zn values (Table 4) represent the treatment means of pooled samples from the two pigs per pen. Red blood cells also were analyzed for Zn concentration on d 36 to determine if a correlation exists between serum and red blood cell Zn concentrations. The red blood cells could not be pooled for analysis; thus, the values (Table 4) represent the means of two pigs bled per pen.

Data were analyzed in a randomized complete block design with pen as the experimental unit. Pigs were blocked on the basis of initial weight, and analysis of variance was performed using the GLM procedure of SAS. Linear, quadratic, and cubic polynomial contrasts were used to determine the effects of increasing dietary Zn.

## Results and Discussion

From d 0 to 11, no differences (P>.05, Table 3) were observed; however, pigs fed 100 ppm of added Zn had numerically the highest ADG and best F/G (.32 lb and 1.55, respectively).

From d 11 to 21 after weaning, ADG was increased from 0 to 100 ppm of added Zn and then plateaued before a second increase for pigs fed 3,200 ppm of Zn (cubic, P<.08). Average daily feed intake increased (linear, P<.0001) with increasing dietary Zn. Feed to gain ratio was not affected (P>.10) by added Zn.

From d 21 to 36, no differences (P>.09) occurred in ADG; however, pigs fed 100 or 200 ppm of Zn had numerically the highest ADG. Average daily feed intake increased (linear, P<.0001) with increasing dietary Zn, and as a result, F/G also became poorer (linear, P<.004). From d 21 to 36 pigs fed 100 ppm of Zn had the best F/G.

Cumulative data (d 0 to 36) showed a tendency for ADG to increase (linear, P<.07) with increasing Zn. Average daily feed intake also increased (linear, P<.0001), with increasing dietary Zn. Feed efficiency became poorer (linear, P<.04) with increasing dietary Zn, with pigs fed 100 ppm of Zn having the best F/G.

Analyzed dietary Zn concentrations (Table 2) generally increased with increasing Zn supplementation. However, some analyzed Zn concentrations showed considerable variation from calculated values. These differences could be results of the 20% variation permitted for Zn analysis.

Serum Zn analysis on d 21 showed that Zn concentrations increased (linear, P<.0001) with increasing dietary Zn. On d 36, serum Zn concentrations increased for pigs fed 100 ppm of added Zn, then plateaued and increased again for pigs fed

3,200 ppm of Zn (cubic, P<.0006). No statistical differences (P>.10) across treatments were observed in red blood cell Zn concentrations, indicating that serum analysis is a better indicator of Zn status.

In conclusion, our results are similar to those of previous research at Kansas State University, showing maximum growth performance when pigs were fed higher levels (above 3,000 ppm) of Zn from zinc oxide in the early starter diets. Our results suggest 100 ppm of Zn from zinc oxide is sufficient to meet the basal requirement; however, 3,200 ppm of Zn was required for a growth-promotional response. The increased growth performance was not observed in the last phase of our experiment, showing that levels of Zn should be decreased after pigs (initially 8 to 10 lb) are approximately 15 lb.

**Table 1. Diet Compositions (As-Fed Basis)**

| Ingredient, % | Day 0 to 5[a] | Day 5 to 11[b] | Day 11 to 21[c] | Day 21 to 36[d] |
|---|---|---|---|---|
| Corn | 38.69 | 45.61 | 51.95 | 58.72 |
| Dried whey | 25.00 | 20.00 | 10.00 | - |
| Soybean meal (46.5% CP) | 12.18 | 21.30 | 28.50 | 34.39 |
| Spray-dried animal plasma | 6.75 | 2.50 | - | - |
| Select menhaden fish meal | 6.00 | 2.50 | - | - |
| Lactose | 5.00 | - | - | - |
| Soy oil | 2.00 | 2.00 | 3.00 | 3.00 |
| Spray-dried blood meal | 1.75 | 2.50 | 2.50 | - |
| Monocalcium phosphate | .69 | 1.26 | 1.59 | 1.48 |
| Limestone | .50 | .76 | .99 | .97 |
| Corn starch[e] | .50 | .50 | .50 | .50 |
| Salt | .25 | .30 | .30 | .35 |
| Vitamin premix | .25 | .25 | .25 | .25 |
| L-Lysine HCl | .15 | .15 | .15 | .15 |
| Trace mineral premix[f] | .15 | .15 | .15 | .15 |
| DL-Methionine | .12 | .15 | .10 | .04 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 |

[a]Diets were formulated to contain 1.70% lysine, .48% methionine, .90% Ca, and .80% P and were fed from d 0 to 5 after weaning.
[b]Diets were formulated to contain 1.55% lysine, .44% methionine, .90% Ca, and .80% P and were fed from d 5 to 11.
[c]Diets were formulated to contain 1.40% lysine, .39% methionine, .85% Ca, and .75% P and were fed from d 10 to 21.
[d]Diets were formulated to contain 1.30% lysine, .36% methionine, .75% Ca, and .70% P and were fed from d 21 to 36.
[e]Zinc oxide replaced corn starch to provide 50, 100, 200, 400, 800, 1,600, 2,400, 3,200 ppm of Zn.
[f]Provided per ton of complete feed: 36 g Mn; 150 g Fe; 15 g Cu; 270 mg I; and 270 mg Se.

**Table 2. Analyzed Zinc Concentrations (ppm) of Diets**

| | Zinc from Zinc Oxide, ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | 0 | 50 | 100 | 200 | 400 | 800 | 1,600 | 2,400 | 3,200 |
| Day 0 to 5 Zn | 47 | 164 | 174 | 226 | 437 | 899 | 1,600 | 2,271 | 3,118 |
| Day 5 to 11 Zn | 140 | 174 | 218 | 346 | 539 | 1,021 | 1,881 | 3,021 | 3,756 |
| Day 11 to 21 Zn | 63 | 84 | 145 | 234 | 260 | 1,064 | 1,848 | 3,224 | 4,151 |
| Day 21 to 36 Zn | 80 | 106 | 137 | 219 | 478 | 787 | 1,529 | 2,321 | 3,399 |

[a]Values (as-fed basis) represent analysis of one sample per diet for each time period.

**Table 3. Influence of Added Zinc from Zinc Oxide on Starter Pig Performance[a]**

| | Zinc from Zinc Oxide, ppm | | | | | | | | | | P < | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | 0 | 50 | 100 | 200 | 400 | 800 | 1,600 | 2,400 | 3,200 | CV | linear | quadratic | cubic |
| Day 0 to 11 | | | | | | | | | | | | | |
| ADG, lb | .25 | .24 | .32 | .29 | .26 | .27 | .26 | .26 | .29 | 20.36 | .74 | .43 | .38 |
| ADFI, lb | .40 | .43 | .49 | .45 | .45 | .44 | .43 | .44 | .46 | 16.48 | .66 | .72 | .35 |
| F/G | 1.64 | 1.82 | 1.55 | 1.56 | 1.75 | 1.74 | 1.69 | 1.77 | 1.61 | 16.86 | .92 | .28 | .75 |
| Day 11 to 21 | | | | | | | | | | | | | |
| ADG, lb | .55 | .54 | .62 | .61 | .59 | .58 | .59 | .60 | .72 | 12.35 | .0002 | .03 | .08 |
| ADFI, lb | .96 | .94 | 1.03 | 1.04 | 1.05 | .97 | 1.05 | 1.11 | 1.21 | 9.72 | .0001 | .13 | .41 |
| F/G | 1.77 | 1.76 | 1.71 | 1.73 | 1.81 | 1.71 | 1.79 | 1.84 | 1.68 | 10.18 | .98 | .25 | .22 |
| Day 0 to 21 | | | | | | | | | | | | | |
| ADG, lb | .39 | .38 | .46 | .44 | .41 | .41 | .42 | .42 | .49 | 13.56 | .01 | .10 | .16 |
| ADFI, lb | .66 | .67 | .75 | .73 | .73 | .69 | .72 | .76 | .81 | 10.60 | .0005 | .30 | .38 |
| F/G | 1.71 | 1.77 | 1.65 | 1.67 | 1.78 | 1.72 | 1.75 | 1.79 | 1.66 | 9.63 | .90 | .15 | .39 |
| Day 21 to 36 | | | | | | | | | | | | | |
| ADG, lb | .94 | 1.05 | 1.14 | 1.14 | 1.11 | 1.07 | 1.13 | 1.11 | 1.08 | 9.86 | .30 | .09 | .36 |
| ADFI, lb | 1.55 | 1.65 | 1.73 | 1.79 | 1.75 | 1.71 | 1.82 | 1.86 | 1.84 | 7.67 | .0001 | .11 | .57 |
| F/G | 1.66 | 1.56 | 1.52 | 1.58 | 1.59 | 1.60 | 1.62 | 1.67 | 1.71 | 7.34 | .004 | .49 | .56 |
| Day 0 to 36 | | | | | | | | | | | | | |
| ADG, lb | .62 | .66 | .74 | .73 | .70 | .69 | .71 | .70 | .74 | 10.00 | .07 | .89 | .20 |
| ADFI, lb | 1.03 | 1.08 | 1.16 | 1.17 | 1.16 | 1.11 | 1.18 | 1.21 | 1.24 | 7.90 | .0001 | .79 | .41 |
| F/G | 1.67 | 1.63 | 1.56 | 1.61 | 1.65 | 1.63 | 1.66 | 1.72 | 1.69 | 6.76 | .04 | .79 | .35 |

[a]A total of 360 weanling pigs (initially 8.6 lb and 12 ± 2 d of age), five pigs per pen and 8 pens per treatment.

**Table 4. Influence of Added Zinc from Zinc Oxide on Serum and Red Blood Cell Zinc Concentration[a]**

| | Zn from Zinc Oxide, ppm | | | | | | | | | P < | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | 0 | 50 | 100 | 200 | 400 | 800 | 1,600 | 2,400 | 3,200 | linear | quadratic | cubic |
| Day 21 Serum Zn, mg/L | .69 | .77 | .93 | .99 | .92 | .95 | 1.19 | 1.81 | 2.46 | .0001 | .0001 | .49 |
| Day 36 Serum Zn, mg/L | .46 | .77 | 1.00 | 1.01 | 1.03 | 1.11 | 1.17 | 1.62 | 2.17 | .0001 | .04 | .0006 |
| Day 36 RBC Zn, mg/L | 7.32 | 7.32 | 7.55 | 7.21 | 7.45 | 7.13 | 7.38 | 6.78 | 7.48 | .61 | .37 | .35 |

[a]Serum values represent treatment means of pooled values of two pigs per pen. Red blood cell (RBC) values represent treatment means of two pigs per pen.

# EFFECTS OF ADDED ZINC FROM ZINC SULFATE OR ZINC SULFATE/ZINC OXIDE COMBINATIONS ON WEANLING PIG GROWTH PERFORMANCE [1]

*J. C. Woodworth, M. D. Tokach [2], J. L. Nelssen, R. D. Goodband, P. R. O'Quinn, R. E. Musser, S. A. Moser, and T. M. Fakler [3]*

## Summary

Three hundred and sixty early-weaned pigs were fed either a control diet containing no added Zn; diets containing added Zn (100, 200, or 400 ppm) from zinc sulfate or a combination of zinc sulfate and zinc oxide (50:50 ratio); or a diet containing 3,000 ppm of added Zn from zinc oxide. No additive effects on growth performance were observed with combinations of zinc sulfate and zinc oxide. Increasing levels of zinc sulfate or increasing the combination of zinc sulfate and zinc oxide had no effect on growth performance. Average daily gain and ADFI were highest for pigs fed diets containing 3,000 ppm of Zn from zinc oxide, which is similar to results of previous research at Kansas State University. To achieve maximum growth performance, 3,000 ppm of Zn from zinc oxide should be added to diets of weanling pigs.

(Key Words: Early-Weaned Pigs, Growth, Zinc.)

## Introduction

A previous study at Kansas State University compared the effects of added Zn from zinc sulfate or a zinc amino acid complex (AvailaZn) to a diet containing no additional Zn and a diet containing 3,000 ppm of Zn from zinc oxide. All diets contained 165 ppm of Zn (zinc oxide) from the trace mineral premix. Although pigs fed diets containing zinc sulfate and AvailaZn had numerically lower ADG and ADFI compared to pigs fed high levels of zinc oxide, all pigs showed improvements in growth performance over those fed the diets containing no additional Zn. It was unclear if the growth response to added zinc sulfate was a true additive growth response to two different inorganic Zn sources (zinc oxide and zinc sulfate) or just a response to higher total Zn concentrations. The objective of this trial was to clarify this response.

## Procedures

A total of 360 weanling pigs (initially 12.1 lb and 18 d of age; Genetipork) was used in a 34 d growth assay to determine the influence of added Zn from zinc sulfate or zinc sulfate and zinc oxide combinations on early-weaned pig growth performance. Pigs were blocked by initial weight and allotted randomly to each of eight dietary treatments. Each treatment had five pigs per pen and nine replications (pens) per treatment.

All experimental diets were fed in meal form. Diets fed from d 0 to 5 were formulated to contain 1.70% lysine, .48% methionine, .90% Ca, and .80% P (Table 1).

---

[1]Appreciation is expressed to Zinpro Corporation, Eden Prairie, MN for parial financial support for this experiment and to Ed Ebert, Norton Pig Company, for supplying the pigs for this experiment, and to Colin Bradley of the London Health Sciences Centre, London, Ontario, Canada for conducting the serum Zn analysis.

[2]Northeast Area Extension Office, Manhattan, KS.

[3]Zinpro Corporation, Eden Prairie, MN.

Diets fed from d 5 to 10 were formulated to contain 1.55% lysine, .44% methionine, .90% Ca, and .80% P. Diets fed from d 10 to 20 were formulated to contain 1.40% lysine, .39% methionine, .85% Ca, and .75% P. Diets fed from d 20 to 34 were formulated to contain 1.30% lysine, .36% methionine, .75% Ca, and .70% P. The eight experimental diets consisted of a negative control diet containing no added Zn; three diets containing added zinc sulfate to provide 100, 200, or 400 ppm of Zn; three diets containing added zinc sulfate and zinc oxide at a 1:1 ratio to achieve total Zn additions of 100, 200, or 400 ppm; and a positive control diet containing 3,000 ppm of added Zn from zinc oxide. Pigs were fed the same experimental Zn concentrations throughout the 34 d study. Zinc sulfate and zinc oxide replaced cornstarch in the negative control diet to form the experimental treatments. The trace mineral premix had no additional Zn.

Pigs were housed in the Kansas State University segregated early-weaning facility. Each pen was 4 × 4 ft and contained one nipple waterer and one self-feeder to provide ad libitum access to feed and water.

Pigs were weighed and feed disappearance was determined on d 0, 5, 10, 20, and 34 to calculate ADG, ADFI, and F/G. Feed samples were collected and analyzed for Zn concentration. Two pigs per pen were selected randomly and bled on days 20 and 34 to determine serum Zn concentration. Samples were centrifuged, and the serum from the two pigs in each pen was pooled for analysis. Water samples were collected and analyzed for Zn concentration.

Data were analyzed as a randomized complete block design with pen as the experimental unit. Linear and quadratic values were obtained for increasing levels of zinc sulfate and zinc sulfate/zinc oxide combinations including the negative control. Contrast statements were used to investigate the mean differences between the two controls, 0 and 3,000 ppm of added Zn from zinc oxide, and the other diets as well as comparing the mean differences of diets containing zinc sulfate to diets containing the combination of zinc sulfate and zinc oxide.

## Results and Discussion

From d 0 to 10, no difference (linear and quadratic, P>.57) occurred in ADG with increasing zinc sulfate, but pigs fed increasing levels of total Zn from the combination of zinc sulfate and zinc oxide had decreasing (linear, P<.01) ADG. Pigs fed the positive control diet containing 3,000 ppm of Zn from zinc oxide had higher (P<.006) ADG and ADFI compared to pigs fed any other diet. Feed to gain ratio worsened (linear, P<.006) for pigs fed increasing total Zn from combinations of zinc sulfate and zinc oxide, which explains the poorer ADG exhibited by pigs fed the combination of 200 ppm of Zn from zinc sulfate and 200 ppm of Zn from zinc oxide. Pigs fed this diet also had poorer (P<.001) F/G compared to pigs fed 400 ppm of Zn from only zinc sulfate. Pigs fed the diet containing 3,000 ppm of Zn had improved (P<.02) F/G compared to pigs fed diets containing zinc sulfate or diets containing zinc sulfate and zinc oxide but did not differ (P<.14) from pigs fed no additional Zn.

From d 10 to 20, no differences (linear and quadratic, P<.15) occurred in ADG, ADFI, or F/G for pigs fed increasing zinc sulfate or increasing total Zn from combinations of zinc sulfate and zinc oxide. Pigs fed diets containing 3,000 ppm of Zn from zinc oxide had higher (P<.0001) ADG and ADFI compared to pigs in all other treatments. Pigs fed the positive control diet tended to have improved (P<.07) F/G compared to pigs fed all other diets. Average daily gain, ADFI, and F/G was not affected (P>.32) by pigs fed zinc sulfate compared to pigs fed diets containing both zinc sulfate and zinc oxide.

From d 20 to 34, ADG, ADFI, and F/G again were not affected (P>.14) by increasing levels of zinc sulfate and increasing levels of total Zn from combined zinc sulfate and zinc oxide. Average daily gain was higher (P<.04) for pigs fed the combination of 50 ppm of Zn from zinc sulfate and 50

ppm of Zn from zinc oxide compared to pigs fed only 100 ppm of Zn from zinc sulfate. Pigs fed the positive control diet had higher (P<.004) ADG than pigs fed diets containing zinc sulfate and tended to have higher (P>.08) ADGs compared to pigs fed diets containing both zinc sulfate and zinc oxide or diets containing no added Zn. Average daily feed intake was higher (P<.001) for pigs fed 3,000 ppm of Zn from zinc oxide compared to all other treatments. Pigs fed diets containing combinations of Zn from zinc sulfate and zinc oxide had higher (P<.05) ADFI than pigs fed diets containing only zinc sulfate. Like ADFI, pigs fed the positive control diet had improved (P<.01) F/G compared to pigs fed any other treatment. Feed efficiency was not different (P>.46) for pigs fed zinc sulfate compared to pigs fed diets containing both zinc sulfate and zinc oxide.

Overall from d 0 to 34, no differences (linear and quadratic, P>.16) in ADG, ADFI, or F/G occurred for pigs fed increasing concentrations of Zn from zinc sulfate or increasing concentrations of total Zn from zinc sulfate and zinc oxide. Pigs fed the diet containing 3,000 ppm of added Zn from zinc oxide had the highest (P<.0009) ADG and ADFI compared to pigs fed all other diets. Pigs fed diets containing only zinc sulfate tended to have higher (P<.09) ADFI compared to pigs fed diets containing both zinc sulfate and zinc oxide but did not differ (P>.24) in ADG and F/G. No differences (P>.08) occurred in F/G between treatments from d 0 to 34.

Feed samples were collected and analyzed for Zn concentrations (Table 2). Zinc concentrations generally increased with increasing additions of Zn. Some variation did occur between calculated and analyzed values. According to AAFCO guidelines, variations of 20% are permitted in Zn analysis. Water samples also were analyzed for Zn concentration and found to contain only 90 ppb Zn, which would not significantly influence growth performance of the pigs.

Serum Zn concentrations at d 20 and 34 (Tables 3 and 4) increased (linear and quadratic, P<.04) with increasing zinc sulfate and increasing total Zn from combinations of zinc sulfate and zinc oxide. Pigs fed the positive control diet containing 3,000 ppm of Zn from zinc oxide had higher (P<.0001) serum Zn concentrations, and pigs fed no additional Zn had lower (P<.05) serum Zn concentrations compared to all pigs in other treatments. No difference (P>.39) occurred in serum Zn concentration for pigs fed only zinc sulfate versus pigs fed both zinc sulfate and zinc oxide.

In conclusion, pigs fed diets containing 3,000 ppm of Zn from zinc oxide had the highest ADG compared to all other treatments. The response in ADG was a result of higher ADFI exhibited by these pigs compared to pigs fed other diets. No consistent differences occurred in ADG, ADFI, or F/G for pigs fed diets containing zinc sulfate compared to pigs fed diets containing both zinc sulfate and zinc oxide. Data from previous trials showed increases in ADG of pigs fed diets containing added Zn versus diets containing no Zn. The lack of response in this trial to basal levels of added Zn could be explained by differences in health status of the pigs and by different genotypes having different Zn requirements. These data suggest that 3,000 ppm of Zn from zinc oxide should be added to diets to maximize weanling pig growth performance.

**Table 1. Diet Compositions (As-Fed Basis)**

| Ingredient, % | Day 0 to 5[a] | Day 5 to 10[b] | Day 10 to 20[c] | Day 20 to 34[d] |
|---|---|---|---|---|
| Corn | 38.69 | 45.66 | 51.95 | 58.72 |
| Dried whey | 25.00 | 20.00 | 10.00 | - |
| Soybean meal (46.5% CP) | 12.18 | 21.30 | 28.50 | 34.39 |
| Spray-dried animal plasma | 6.75 | 2.50 | - | - |
| Select menhaden fish meal | 6.00 | 2.50 | - | - |
| Lactose | 5.00 | - | - | - |
| Soy oil | 2.00 | 2.00 | 3.00 | 3.00 |
| Spray-dried blood meal | 1.75 | 2.50 | 2.50 | - |
| Monocalcium phosphate | .70 | 1.27 | 1.60 | 1.48 |
| Limestone | .51 | .77 | 1.0 | .97 |
| Cornstarch[e] | .50 | .50 | .50 | .50 |
| Salt | .25 | .30 | .30 | .35 |
| Vitamin premix | .25 | .25 | .25 | .25 |
| L-Lysine HCL | .15 | .15 | .15 | .15 |
| Trace mineral premix[f] | .15 | .15 | .15 | .15 |
| DL-Methionine | .12 | .15 | .10 | .04 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 |

[a]Diets were formulated to contain 1.70% lysine, .48% methionine, .90% Ca, and .80% P and were fed from d 0 to 5 after weaning.
[b]Diets were formulated to contain 1.55% lysine, .44% methionine, .90% Ca, and .80% P and were fed from d 5 to 11.
[c]Diets were formulated to contain 1.40% lysine, .39% methionine, .85% Ca, and .75% P and were fed from d 10 to 21.
[d]Diets were formulated to contain 1.30% lysine, .36% methionine, .75% Ca, and .70% P and were fed from d 21 to 36.
[e]Zn sources replaced corn starch to provide 100, 200, 400,or 3,000 ppm of added Zn.
[f]Provided per ton of complete feed: 36 g Mn; 150 g Fe; 15 g Cu; 270 mg I; and 270 mg Se.

**Table 2. Analyzed Zinc Concentrations (ppm) of Formulated Diets[a]**

| | | Added Zn (ppm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Zinc Sulfate | 0 | 100 | 50 | 200 | 100 | 400 | 200 | 0 |
| Item | Zinc Oxide | 0 | 0 | 50 | 0 | 100 | 0 | 200 | 3,000 |
| Day 0 to 5 | | | | | | | | | |
| Zn | | 38 | 217 | 140 | 189 | 185 | 438 | 374 | 2,700 |
| Day 5 to 10 | | | | | | | | | |
| Zn | | 44 | 155 | 93 | 131 | 229 | 178 | 361 | 2,440 |
| Day 10 to 20 | | | | | | | | | |
| Zn | | 59 | 117 | 97 | 155 | 253 | 379 | 404 | 2,529 |
| Day 20 to 34 | | | | | | | | | |
| Zn | | 230 | 116 | 116 | 165 | 149 | 269 | 234 | 1,944 |

[a]Values (as-fed basis) represent analysis of one sample per diet for each time period.

**Table 3. Effects of Added Zinc from Zinc Sulfate or Zinc Sulfate/Zinc Oxide Combinations on Weanling Pig Growth Performance[a]**

| | | Added Zn (ppm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Zinc Sulfate | 0 | 100 | 50 | 200 | 100 | 400 | 200 | 0 |
| Item | Zinc Oxide | 0 | 0 | 50 | 0 | 100 | 0 | 200 | 3,000 |
| Day 0 to 10 | | | | | | | | | |
| ADG, lb | | .38 | .35 | .35 | .33 | .35 | .36 | .32 | .47 |
| ADFI, lb | | .47 | .46 | .48 | .44 | .45 | .44 | .47 | .55 |
| F/G | | 1.29 | 1.35 | 1.38 | 1.38 | 1.29 | 1.24 | 1.51 | 1.19 |
| Day 10 to 20 | | | | | | | | | |
| ADG, lb | | .68 | .68 | .72 | .69 | .68 | .66 | .68 | .88 |
| ADFI, lb | | 1.01 | .99 | 1.05 | .95 | .96 | .94 | .97 | 1.25 |
| F/G | | 1.55 | 1.49 | 1.45 | 1.39 | 1.42 | 1.44 | 1.43 | 1.42 |
| Day 20 to 34 | | | | | | | | | |
| ADG, lb | | 1.20 | 1.15 | 1.25 | 1.19 | 1.20 | 1.13 | 1.16 | 1.28 |
| ADFI, lb | | 1.88 | 1.91 | 2.03 | 1.87 | 1.97 | 1.83 | 1.92 | 2.23 |
| F/G | | 1.56 | 1.66 | 1.62 | 1.57 | 1.63 | 1.62 | 1.66 | 1.75 |
| Day 0 to 34 | | | | | | | | | |
| ADG, lb | | .81 | .77 | .83 | .79 | .80 | .80 | .77 | .92 |
| ADFI, lb | | 1.21 | 1.22 | 1.28 | 1.18 | 1.23 | 1.21 | 1.21 | 1.44 |
| F/G | | 1.51 | 1.57 | 1.54 | 1.50 | 1.53 | 1.51 | 1.58 | 1.57 |
| Day 20 Serum[b] | | | | | | | | | |
| Zn, mg/L | | .41 | .77 | .88 | .94 | .88 | .88 | .91 | 1.74 |
| Day 34 Serum[b] | | | | | | | | | |
| Zn, mg/L | | .93 | .97 | 1.09 | 1.16 | 1.13 | 1.11 | 1.16 | 1.78 |

[a]A total of 360 weanling pigs (initially 12.1 lb and 18 d of age), five pigs per pen and nine pens per treatment.
[b]Values represent treatment means of pooled samples from two pigs per pen.

**Table 4. Statistical Analysis of Mean Values (P <)**

| | Zinc Sulfate | | Combination | | | Contrasts[a] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Lin. | Quad. | Lin. | Quad. | CV | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Day 0 to 10 | | | | | | | | | | | | | | |
| ADG, lb | .41 | .28 | .01 | .89 | 15.3 | .001 | .93 | .45 | .37 | .11 | .10 | .0001 | .0001 | .96 |
| ADFI, lb | .09 | .79 | .74 | .44 | 11.9 | .006 | .65 | .72 | .11 | .16 | .70 | .0001 | .0003 | .16 |
| F/G | .76 | .19 | .006 | .21 | 11.0 | .14 | .64 | .24 | .001 | .53 | .09 | .02 | .0007 | .12 |
| Day 10 to 20 | | | | | | | | | | | | | | |
| ADG, lb | .75 | .85 | .79 | .77 | 14.7 | .0001 | .31 | .88 | .66 | .82 | .75 | .0001 | .0001 | .45 |
| ADFI, lb | .22 | .75 | .21 | .95 | 11.4 | .0001 | .32 | .85 | .58 | .26 | .67 | .0001 | .0001 | .32 |
| F/G | .15 | .16 | .18 | .27 | 10.2 | .07 | .61 | .70 | .84 | .07 | .05 | .66 | .75 | .86 |
| Day 20 to 34 | | | | | | | | | | | | | | |
| ADG, lb | .25 | .92 | .24 | .34 | 8.6 | .13 | .04 | .72 | .56 | .27 | .89 | .004 | .08 | .08 |
| ADFI, lb | .57 | .74 | .95 | .21 | 9.7 | .0002 | .20 | .26 | .32 | .96 | .18 | .0001 | .001 | .05 |
| F/G | .54 | .69 | .14 | .62 | 6.7 | .0006 | .47 | .25 | .40 | .20 | .08 | .003 | .01 | .46 |
| Day 0 to 34 | | | | | | | | | | | | | | |
| ADG, lb | .49 | .78 | .16 | .45 | 8.4 | .0009 | .09 | .74 | .93 | .32 | .86 | .0001 | .0001 | .26 |
| ADFI, lb | .47 | .99 | .73 | .38 | 9.1 | .0001 | .21 | .37 | .43 | .64 | .45 | .0001 | .0001 | .09 |
| F/G | .73 | .77 | .19 | .95 | 4.9 | .12 | .50 | .35 | .08 | .60 | .17 | .17 | .59 | .24 |
| Day 20 Serum | | | | | | | | | | | | | | |
| Zn, mg/L | .0001 | .0001 | .0001 | .0001 | 19.86 | .0001 | .21 | .51 | .79 | .0001 | .0001 | .0001 | .0001 | .62 |
| Day 34 Serum | | | | | | | | | | | | | | |
| Zn, mg/L | .007 | .097 | .0007 | .04 | 16.73 | .0001 | .20 | .74 | .59 | .05 | .01 | .0001 | .0001 | .39 |

[a]Contrasts were 1) neg control vs pos control, 2) 100 vs 50/50, 3) 200 vs 100/100, 4) 400 vs 200/200, 5) neg control vs zinc sulfate, 6) neg control vs combination, 7) pos control vs zinc sulfate, 8) pos control vs combination, and 9) zinc sulfate vs combination.

# INFLUENCE OF SOYBEAN MEAL VARIETY AND PROCESSING TEMPERATURE ON THE GROWTH PERFORMANCE OF PIGS FROM 25 TO 45 LB [1]

*J. A. Loughmiller, J. L. Nelssen, R. D. Goodband, M. D. Tokach [2], T. T. Lohrman [3], M. De La Llata, P. R. O'Quinn, J. C. Woodworth, S. Moser, and G. S. Grinstead*

## Summary

Three hundred ninety high-lean growth pigs were used in a 17 d growth assay from 25 to 45 lb. Treatments consisted of soybean meal (SBM) from either high-oleic or check-line soybean varieties processed under pilot-plant processing conditions at four temperature ranges (80-85, 85-90, 90-95, 100-105°C). Positive and negative controls were made using commercially obtained SBM (46.5% CP). Total dietary lysine was maintained at .95% except for the positive control (1.30%). Pigs fed commercial SBM with 1.30% dietary lysine had increased ADG and better F/G than pigs fed any other treatment. A SBM variety × processing temperature interaction was observed for ADG and F/G for each growth period. The interaction likely resulted from improvement in ADG and F/G with high-oleic SBM, but not the check-line SBM, as processing temperature increased. Pigs fed high-oleic SBM had improved ADG and F/G throughout all growth periods as processing temperature increased, so pigs fed high-oleic SBM processed at 80-85°C had poorer growth performance than pigs fed any other treatment. These results indicate that pigs fed high-oleic SBM processed above 80-85°C have similar performance to pigs fed SBM from other varieties.

(Key Words: High-Oleic Soybeans, Processing Temperature, Growth, Nursery Pigs.)

## Introduction

Grains and oilseeds are being improved genetically to provide a specific trait or traits for quality or agronomic reasons. Changes in nutrient content and/or composition can provide direct improvements in diet cost and growth efficiency for the swine industry. Increasing the oleic acid content of soybeans may increase demand for soybean oil used in restaurant and home food preparation. As demand for high-oleic soybean oil increases, larger amounts of soybean meal (SBM) from high-oleic soybeans will be produced. However, potential differences in SBM processing conditions to maximize oil extraction from high-oleic soybeans also may affect growth performance of pigs. Additionally, it is unknown if SBM produced from high-oleic soybeans will provide similar levels of growth performance as SBM from other more traditional varieties. Therefore, our objective was to determine the growth performance of pigs fed either high-oleic soybean meal or a standard check-line SBM processed under pilot plant conditions using different temperature ranges.

## Procedures

Three hundred and ninety high-lean growth pigs (Newsham Hybrids) were blocked by weight (initially 22.3 lb and 35 d of age) and allotted to one of 10 dietary treatments. There were four or five pigs per pen (equal number of pigs per pen by block) and

[1]The authors thank Dupont Quality Grains, Des Moines, IA for partial financial and product support of this experiment.

[2]Northeast Area Extension Office, Manhattan, KS.

[3]Dupont Quality Grains, Des Moines, IA.

eight replicate pens per treatment. The experimental diets consisted of a 2 × 4 factorial arrangement with main effects including SBM variety (high-oleic and check-line SBMs) and processing temperature (80-85, 85-90, 90-95, and 100-105°C) with positive and negative controls using commercially obtained SBM (46.5% CP).

The high-oleic and check-line SBMs were processed by Dupont using commercial pilot-plant processing conditions with standard hexane processing. Conditioning steam and top tray temperature were varied, resulting in the four different processing conditions. The commercial SBM was obtained through normal industry channels by the KSU Animal Sciences and Industry Feed Mill.

All diets were corn-SBM-based. Analyzed total amino acid values for the SBMs were used to formulate diets to .95% lysine, except the positive control diet, which was formulated to 1.30% lysine. All pigs were fed common SEW, transition, and phase 2 diets according to KSU recommendations until 21 d postweaning, when they were placed on their respective treatments. All experimental diets were corn-SBM-based (Table 1). The positive control (1.30% lysine) contained .15% lysine HCl to minimize the use of additional SBM to meet the higher lysine level, while maintaining all other amino acids at or above an ideal amino acid pattern relative to lysine. All diets in this experiment were fed in meal form from d 21 to 38 postweaning.

Pigs were housed in the KSU segregated early-weaning nursery in 4 × 4 ft pens. They were allowed ad libitum access to feed and water through a four-hole dry feeder and one nipple waterer per pen. The pigs were weighed and feed disappearance was measured at 7 d intervals and at the termination of the trial to determine ADG, ADFI, and F/G.

The data were analyzed as a randomized complete block design in a 2 × 4 factorial arrangement. Pigs were blocked by initial weight with pen as the experimental unit. Analysis of variance was performed using general linear model procedures with linear and quadratic polynomial contrasts to determine the effects of increasing processing temperature within variety on pig performance. Nonorthogonal contrasts also were analyzed to determine if differences in performance existed between the means of individual Dupont varieties or between the Dupont varieties and the positive or negative control.

## Results

Pigs fed the positive control diet formulated to 1.30% dietary lysine had increased ADG and better F/G than pigs fed any other treatment ($P<.05$; Table 2). A SBM variety × processing temperature interaction was observed for ADG and F/G during each growth period ($P<.05$). Average daily gain and F/G improved during each growth period, with the exception of d 0 to 7 ADG, as processing temperature increased (linear, $P<.02$; quadratic, $P<.01$). However, the improvements in ADG and F/G in Table 2 were primarily results of pigs fed diets containing high-oleic SBM having improved ADG and F/G throughout all growth periods as processing temperature increased (quadratic $P<.01$; Table 3). Thus, pigs fed diets containing high-oleic SBM processed at 80-85°C had poorer growth performance than pigs fed any other treatment. The difference between pigs fed diets containing high-oleic SBM processed at 80-85°C and pigs fed any other treatment at the same lysine level also would explain the observed interactions associated with the main effects of SBM variety and processing temperature. From d 0 to 7 and d 0 to 17, pigs fed diets containing check-line SBM had decreased performance compared to pigs fed the negative control diets (.95% lysine) containing commercial SBM ($P>.05$). In contrast, from d 7 to 14 and d 14 to 17 pigs fed diets containing check-line SBM had similar performance to pigs fed the negative control diet containing commercial SBM ($P>.17$).

## Discussion

These results indicate that .95% total dietary lysine is insufficient to maximize growth performance of 25 to 50 lb lean-growth potential pigs. This is similar to results reported previously in the 1994 KSU Swine Day Report of Progress, which indicated that growth performance of 25 to 50 lb high health pigs was maximized between 1.05 and 1.15% apparent digestible lysine. These diets, except the positive control, were formulated to a lower lysine level so that any effect of amino acid availability related to soybean variety or processing temperature on growth performance would be readily apparent.

These results also indicate that pigs fed diets containing high-oleic SBM have similar performance when compared to pigs fed diets containing either commercial SBM or check-line SBM formulated to similar lysine levels, when the high-oleic SBM is processed above 80-85°C. It seems unlikely that pigs fed diets containing high-oleic SBM processed at 80-85°C should have dramatically different growth performance than pigs fed diets containing check-line SBM processed at 80-85°C. A previous experiment by Dupont with chickens designed similarly to this experiment observed no differences in growth performance with various processing temperatures. Thus, difficulties in control using pilot-plant processing conditions probably contributed to the decreased performance of pigs fed diets containing high-oleic SBM processed at 80-85°C when compared to other treatments at similar dietary lysine levels. The observed differences in growth performance between the negative control treatments containing commercial SBM and the check-line SBM treatments were inconsistent across growth periods and do not represent large numerical differences in performance.

**Table 1. Diet Composition (As-Fed Basis)[a] %**

| Item | Commercial SBM | | High-Oleic SBM | Check-Line SBM |
|---|---|---|---|---|
| Dietary lysine, % | 1.30 | .95 | .95 | .95 |
| Corn | 58.10 | 66.67 | 67.01 | 67.21 |
| Soybean meal, 46.5% CP | 34.55 | 26.10 | --- | --- |
| High-oleic soybean meal | --- | --- | 25.75 | --- |
| Check-line soybean meal | --- | --- | --- | 25.55 |
| Soybean oil | 3.00 | 3.00 | 3.00 | 3.00 |
| Monocalcium phosphate | 1.57 | 1.73 | 1.74 | 1.74 |
| Limestone | .80 | .75 | .75 | .75 |
| Medication[b] | 1.00 | 1.00 | 1.00 | 1.00 |
| Salt | .35 | .35 | .35 | .35 |
| Vitamin premix | .25 | .25 | .25 | .25 |
| Trace mineral premix | .15 | .15 | .15 | .15 |
| Lysine HCl | .15 | --- | --- | --- |

[a]All diets were formulated to contain .9% Ca and .8% P.
[b]Provided 50 g/ton carbadox.

**Table 2. Effects of Soybean Meal Variety with 1.30 or .95% Lysine and Four Processing Temperatures (°C) on 25 to 45 lb Pig Performance[a]**

| | Commercial | | High-Oleic (.95%) | | | | Check-Line (.95%) | | | | | Probability[b] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | 1.30 | .95 | 80-85 | 85-90 | 90-95 | 100-105 | 80-85 | 85-90 | 90-95 | 100-105 | CV | linear | quadratic | SBM × Temp.[c] |
| Day 0 to 7 | | | | | | | | | | | | | | |
| ADG, lb[d] | 1.23 | .99 | .70 | .95 | .84 | .92 | 1.00 | .87 | .91 | .87 | 9.68 | .44 | .37 | .01 |
| ADFI, lb | 1.76 | 1.69 | 1.67 | 1.61 | 1.54 | 1.63 | 1.74 | 1.64 | 1.66 | 1.68 | 6.75 | .40 | .01 | .68 |
| F/G[d] | 1.44 | 1.71 | 2.38 | 1.72 | 1.84 | 1.79 | 1.75 | 1.92 | 1.82 | 1.95 | 8.83 | .02 | .01 | .01 |
| Day 7 to 14 | | | | | | | | | | | | | | |
| ADG, lb[d] | 1.43 | 1.21 | .84 | 1.11 | 1.15 | 1.09 | 1.15 | 1.16 | 1.13 | 1.19 | 9.06 | .01 | .01 | .01 |
| ADFI, lb | 2.13 | 2.11 | 2.00 | 2.03 | 2.00 | 2.01 | 2.14 | 2.05 | 2.05 | 2.13 | 5.57 | .89 | .13 | .38 |
| F/G[d] | 1.49 | 1.74 | 2.42 | 1.84 | 1.74 | 1.86 | 1.86 | 1.79 | 1.82 | 1.80 | 8.86 | .01 | .01 | .01 |
| Day 14 to 17 | | | | | | | | | | | | | | |
| ADG, lb[d] | 1.53 | 1.31 | .70 | 1.33 | 1.29 | 1.32 | 1.23 | 1.35 | 1.35 | 1.12 | 21.9 | .07 | .01 | .01 |
| ADFI, lb | 2.52 | 2.45 | 2.18 | 2.51 | 2.33 | 2.41 | 2.43 | 2.47 | 2.40 | 2.41 | 8.60 | .44 | .31 | .23 |
| F/G[d] | 1.69 | 1.92 | 3.56 | 1.96 | 1.83 | 1.86 | 2.03 | 1.86 | 1.87 | 2.28 | 26.7 | .01 | .01 | .02 |
| Day 0 to 17 | | | | | | | | | | | | | | |
| ADG, lb[d] | 1.36 | 1.13 | .76 | 1.08 | 1.04 | 1.05 | 1.10 | 1.06 | 1.07 | 1.04 | 7.33 | .01 | .01 | .01 |
| ADFI, lb | 2.02 | 1.98 | 1.89 | 1.92 | 1.85 | 1.91 | 2.02 | 1.94 | 1.94 | 1.98 | 5.27 | .93 | .11 | .44 |
| F/G[d] | 1.50 | 1.75 | 2.49 | 1.80 | 1.78 | 1.83 | 1.84 | 1.83 | 1.81 | 1.91 | 5.45 | .01 | .01 | .01 |

[a]A total of 390 pigs was weaned at 14 d of age, and weight average was 9.3 lb. They were fed a common three stage diet series until being placed on test at d 21 postweaning. At trial initiation, the average pig weight was 22.3 lb. The average ending weight was 39.8 lb.
[b]The linear and quadratic probabilities on this table are for the main effect of processing temperature, without regard for variety.
[c]Main effects of Dupont soybean meal variety by processing temperature.
[d]Contrast of 1.30% dietary lysine SBM treatment vs. all other treatments (P<.05).

**Table 3. Orthogonal Contrasts of Linear and Quadratic Effects within Soybean Meal Variety and Nonorthogonal Contrasts of Commercial Soybean Meal vs. High-Oleic Soybean Meal[b] and Check-Line Soybean Meal[c]**

| | Probability (P<) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | HOSBM | | HOSBM vs. .95% Lysine SBM | HOSBM vs. CLSBM | CLSBM | | CLSBM vs. 95% Lysine SBM | 1.13% Lysine SBM vs. .95% Lysine SMB |
| Item | linear | quadratic | | | linear | quadratic | | |
| D 0 to 7 | | | | | | | | |
| ADG, lb | .02 | .01 | .01 | .01 | .06 | .25 | .03 | .01 |
| ADFI, lb | .53 | .02 | .10 | .02 | .61 | .22 | .87 | .17 |
| F/G | .01 | .01 | .01 | .08 | .11 | .74 | .02 | .01 |
| D 7 to 14 | | | | | | | | |
| ADG, lb | .01 | .01 | .01 | .01 | .51 | .54 | .17 | .01 |
| ADFI, lb | .95 | .98 | .02 | .01 | .90 | .03 | .67 | .36 |
| F/G | .01 | .01 | .01 | .01 | .48 | .61 | .26 | .01 |
| D 14 to 17 | | | | | | | | |
| ADG, lb | .01 | .01 | .18 | .16 | .29 | .13 | .66 | .14 |
| ADFI, lb | .15 | .14 | .27 | .16 | .76 | .99 | .83 | .31 |
| F/G | .01 | .01 | .09 | .04 | .13 | .07 | .70 | .52 |
| D 0 to 17 | | | | | | | | |
| ADG, lb | .01 | .01 | .01 | .01 | .27 | .89 | .04 | .01 |
| ADFI, lb | .79 | .55 | .03 | .01 | .76 | .15 | .72 | .16 |
| F/G | .01 | .01 | .01 | .01 | .18 | .22 | .02 | .01 |

[a]Commercial soybean meal is abbreviated as SBM.
[b]High-oleic soybean meal is abbreviated as HOSBM.
[c]Check-line soybean meal is abbreviated as CLSBM.

*Swine Day 1998*

# NUTRITIONAL VALUE OF A TRANSGENIC HIGH-LYSINE, HIGH-OIL CORN FOR YOUNG PIGS [1]

***P. R. O'Quinn, J. L. Nelssen, R. D. Goodband, D. A. Knabe [2], J. C. Woodworth, M. D. Tokach [3], and T. T. Lohrmann [4]***

## Summary

Two trials were conducted to compare the nutritional adequacy of high-lysine, high-oil corn (.408% lysine, 6.21% fat) and high-oil corn (.289% lysine, 5.97% fat) for young growing pigs. Experiment 1 used four barrows fitted with ileal T-cannulas in a crossover design digestion study. Diets contained 8.5% casein and an equal amount of lysine from the test corn. Apparent ileal digestibilities of amino acids, GE, DM, CP, and ash were similar between diets. Experiment 2 used segregated early-weaned barrows in a 2 × 2 factorially designed growth trial. Main effects were corn type and dietary lysine (.80 or 1.15% digestible lysine). Increasing digestible lysine increased ADG and improved F/G regardless of corn variety. Within each lysine level, corn type did not affect ADG, ADFI, or F/G. The results of these studies indicate that the lysine in high-lysine, high-oil corn is as available as the lysine in high-oil corn and that high-lysine, high-oil corn can be used successfully in swine diets.

(Key Words: Digestibility, Growth, High-Oil Corn, High-Lysine High-Oil Corn, Segregated Early-Weaned Pigs.)

## Introduction

Advances in biotechnology have generated specialty grains, such as high-oil corn, which has a slightly higher lysine content and more oil content than conventional yellow dent corn. High-oil corn is generally accepted a suitable replacement for conventional corn and also can replace a portion of the oil or fat typically added to swine diets. Recently, a high-lysine, high-oil corn variety was developed that contains about 29% more lysine than high-oil corn and 36% more than conventional corn. This high-lysine, high-oil corn has not been evaluated as a feedstuff for swine. Therefore, the objectives of these studies were to compare the apparent ileal digestibility of the amino acids in high-lysine, high-oil corn and high-oil corn and to compare growth performance of pigs fed diets containing these grains formulated on a digestible amino acid basis.

## Procedures

**General.** Two experiments were conducted to evaluate the nutritional adequacy of high-lysine, high-oil corn for growing pigs. Pigs used in Exp. 1 were terminal offspring of PIC L326 sows × C22 boars, and pigs used in Exp. 2 were PIC C22 barrows. Feedstuffs for both experiments were analyzed prior to

[1]Appreciation is expressed to Optimum Quality Grains, Des Moines, IA, for partial financial support and for providing the corns, to Edward J. Gregg, Texas A&M University, for technical assistance; and to Henry's Ltd., Longford, KS, for providing the pigs used in Exp. 2.

[2]Department of Animal Science, Texas A&M University, College Station, TX.
[3]Northeast Area Extension Office, Manhattan, KS.
[4]Optimum Quality Grains, Des Moines, IA.

the initiation of the trials, and complete diets were analyzed after the completion of both trials (Table 1). All procedures were approved by the Kansas State University Institutional Animal Care and Use Committee (Protocol Nos. 1438 and 1440).

**Experiment 1.** Four nonlittermate barrows each were fitted with a simple T-cannula approximately 15 cm anterior to the ileocecal valve. After a 10-d recovery period, the pigs were used in a crossover design digestion study to compare the apparent ileal digestibility of nutrients in high-oil corn and high-lysine, high-oil corn. Composition of the experimental diets is given in Table 2. Both diets were fed in meal form and were based on corn and casein and contained .2% chromic oxide as an indigestible marker. These diets were formulated to be isolysinic and isocaloric with equal fiber contents. This was accomplished by altering the amounts of cornstarch, corn oil, and cellulose in the high-lysine, high-oil corn diet. Both diets contained 8.5% casein and equal amounts of lysine from the test corn. The corn for both diets was ground to a mean particle size of 650 microns.

Each period consisted of 4 d of diet adjustment followed by 2 days (8.5 h/d) of ileal digesta collection. We waited 24 h between each day of ileal collection to prevent any possibility of dehydration with the relatively young pigs. Pigs were fed the same amount each day within each period. Each day's ration was divided equally between meals at 0630 and 1730. Daily feed intakes were 2.0 and 2.4 lb/d for periods 1 and 2, respectively. Water was provided manually at the rate of 2:1 water:feed (wt/wt) twice daily. Mean pig weights at the beginning of period 1 and at the end of period 2 were 44.1 and 58.3 lb, respectively.

Ileal digesta were collected between 0630 and 1500 by attaching a latex balloon to the opened cannula. Digesta in the balloon were collected every 15 min or more often if needed and stored on ice during the 8.5-h collection period. At the end of each day, a 200-g subsample was frozen. The two samples for each pig were combined, freeze-dried, and ground before chemical analyses for Cr, CP, ash, DM, GE, and individual amino acids. All nutrient digestibilities were calculated using chromic oxide as an indigestible marker.

Data from the digestion trial were analyzed initially as a crossover design that included the effects of pig, period, and pig within period. The effect of period and/or pig was significant only for ash (pig, P=.03; period, P=.09). Thus, the data were subsequently analyzed as a completely randomized design.

**Experiment 2.** One hundred segregated early-weaned barrows (initially 18.4 lb) were allotted randomly by body weight to one of five dietary treatments with four pigs per pen and five replicate pens per treatment. Pigs were weaned at 17 ± 2 d of age (average weaning weight of 12.84 lb) and were allotted to treatment when the trial was initiated 10 d later. Prior to the initiation of the trial, all pigs were fed a complex nutrient dense diet based on corn, soybean meal, fish meal, animal plasma, bloodmeal, and whey, which was formulated to contain 1.60% lysine, .90% total calcium, and .80% total phosphorus.

Five diets were evaluated (Table 3). Four diets were arranged in a 2 × 2 factorial with corn source and dietary lysine level as the main effects. Lysine levels were chosen to be either deficient (.80% digestible lysine) or adequate (1.15% digestible lysine). Within each lysine level, diets contained equal amounts of corn and all other ingredients, except L-lysine•HCl, which was added to the high-oil corn diets at the expense of cornstarch. Crystalline lysine was assumed to be 100% digestible, and high-oil corn and high-lysine, high-oil corn were estimated to have digestibilities of 68 and 72%, respectively, based on results of the digestion experiment. Crystalline methionine, trypto-phan, and threonine were added to all diets to ensure their adequacy. Thus, within lysine level, any differences in pig performance should have been attributable to differences in bio-availability of lysine. The fifth diet consisted of the .80% lysine high-oil corn diet supple-

mented with additional L-lysine•HCl (.975% digestible lysine) to verify that lysine was the limiting amino acid in the low-lysine diets.

Corns were ground to a mean particle size of 725 microns. All diets were fed in meal form. Pigs were housed in an environmentally controlled nursery in 4 × 4 ft pens with tri-bar flooring and allowed ad libitum access to feed through a five-hole self-feeder and water through a single-nipple waterer. Weight gains and feed intakes were measured at d 10 of the trial and used to determine ADG, ADFI, and F/G.

Data were analyzed as a 2 × 2 factorial plus a control with main effects of corn type (high-oil corn or high-lysine, high-oil corn) and lysine level (.80 or 1.15% apparent digestible lysine). The control diet was compared to the average of the .80% apparent digestible lysine diets using a single degree of freedom contrast. Pen was the experimental unit in all analyses.

## Results and Discussion

**Experiment 1.** Digestibility values of high-lysine, high-oil corn and high-oil corn for individual amino acids, DM, CP, ash, and GE were similar (P>.40; Table 4). Note that the digestibility values in Table 4 are for diets containing 8.5% casein. Casein generally is assumed to be 100% digestible. Thus, actual digestibility values for the individual amino acids for each corn type can be calculated by difference using the analyzed compositions of the corns and casein (Table 1), percentage composition of the diets (Table 2), and dietary digestibility values (Table 4). However, care must be taken when evaluating actual digestibility values for amino acids other than lysine. Because of the experimental design, the relative amounts of other amino acids in high-lysine, high-oil corn are less than those in high-oil corn; thus, digestibility values for other amino acids in high-lysine, high-oil corn will be lower than for those in high-oil corn. In reality, digestibility of all amino acids in both corn types are similar.

**Experiment 2.** The interactions of dietary lysine level and corn type were nonsignificant (P≥.15) for ADG, ADFI, and F/G. Increasing dietary digestible lysine from .80 to 1.15% increased (P<.001) ADG and F/G; ADFI was not affected. Performance of pigs fed high-oil corn or high-lysine, high-oil corn was similar, indicating equal nutritional value for both types. This suggests that the lysine in high-lysine, high-oil corn is as available as the lysine in high-oil corn and the L-lysine•HCl in the high-oil corn diet.

Increasing lysine in the high-oil corn diet from .80 to .975% increased growth (P=.17) and improved F/G (P=.15) numerically. Although the responses were not significant, they fit the linear increase in performance found with increasing lysine (Figure 1), indicating that lysine was the limiting nutrient in the .80% lysine diets.

These results indicate that the lysine in high-lysine, high-oil corn is highly available and that high-lysine, high-oil corn can be used in place of conventional yellow dent corn or high-oil corn in swine diets without changing growth performance when substituted on a nutrient-for-nutrient basis. High-lysine, high-oil corn should offer the potential to formulate swine diets using less synthetic lysine and/or soybean meal and energy sources such as soybean oil, choice white grease, or poultry fat. However, care must be taken in formulating diets containing high-lysine, high-oil corn. All corn varieties typically have a poor amino acid profile, and the high-lysine level in high-lysine, high-oil corn increases this problem. This is because other amino acids have not been altered. Thus, tryptophan or threonine is more likely to be deficient when high-lysine, high-oil corn is used, because less soybean meal will be included in diets. However, when properly utilized, high-lysine, high-oil corn is an excellent grain source for swine that should offer the potential to lower diet costs.

**Table 1. Analyzed Composition of Experimental Feedstuffs for Exp. 1 and 2 (As-Fed Basis)[a]**

| | High-Oil Corn Variety | | | Spray-Dried | SBM, |
|---|---|---|---|---|---|
| Item, % | Normal | High-lysine | Casein | Whey | 46.5% CP |
| DM | 85.60 | 89.20 | 89.78 | 97.20 | 88.10 |
| CP | 8.17 | 9.72 | 73.12 | ---- | ---- |
| Crude fat | 5.97 | 6.21 | .25 | ---- | ---- |
| Amino acids: | | | | | |
| Arginine | .419 | .447 | 2.79 | .263 | 3.407 |
| Histidine | .241 | .243 | 2.26 | .210 | 1.240 |
| Isoleucine | .261 | .304 | 3.70 | .650 | 2.192 |
| Leucine | .970 | 1.247 | 7.16 | 1.163 | 3.772 |
| Lysine | .289 | .408 | 5.92 | .927 | 3.024 |
| Methionine | .163 | .196 | 2.15 | .166 | .741 |
| Phenylalanine | .387 | .471 | 3.94 | .318 | 2.391 |
| Threonine | .287 | .326 | 3.16 | .737 | 1.871 |
| Valine | .379 | .434 | 4.75 | .644 | 2.330 |
| Alanine | .609 | .761 | 2.34 | .603 | 2.082 |
| Aspartic acid | .609 | .629 | 5.35 | 1.181 | 5.637 |
| Cysteine | .182 | .205 | .38 | .285 | .720 |
| Glutamic acid | 1.527 | 1.827 | 16.79 | 1.996 | 9.127 |
| Glycine | .339 | .351 | 1.43 | .163 | 1.928 |
| Serine | .391 | .464 | 4.18 | .543 | 2.390 |
| Tyrosine | .303 | .373 | 4.27 | .292 | 1.902 |

[a]Values are combined means of analysis from Optimum Quality Grains and a commercial laboratory.

**Table 2. Composition of Diets for Exp. 1 (As-Fed Basis)[a]**

| | Dietary Treatment | |
|---|---|---|
| Item, % | High-oil corn | High-lysine, high-oil corn |
| High-oil corn | 86.96 | ---- |
| High-lysine, high-oil corn | ---- | 61.60 |
| Cornstarch | ---- | 23.29 |
| Casein | 8.50 | 8.50 |
| Monocalcium phosphate | 1.60 | 1.94 |
| Corn oil | ---- | 1.37 |
| Antibiotic[b] | 1.00 | 1.00 |
| Limestone | .99 | .84 |
| Cellulose[c] | ---- | .51 |
| Salt | .35 | .35 |
| Vitamin premix | .25 | .25 |
| Chromic oxide | .20 | .20 |
| Trace mineral premix | .15 | .15 |
| Total | 100.00 | 100.00 |

[a]Diets were formulated to be isolysinic (.80% total lysine) and contained .75% total Ca and .65% total P. Calorie and fiber contents were balanced across treatments by adding corn oil and cellulose to the high-lysine, high-oil corn diet.
[b]Provided 50 g/ton carbadox.
[c]Solka Floc® 300 powdered cellulose.

**Table 3. Composition of Diets for Exp. 2 (As-Fed Basis)[a]**

| | Digestible Lysine Level | | | | |
|---|---|---|---|---|---|
| | .80% | | 1.15% | | .975% |
| Item, % | HOC | HLYSHOC | HOC | HLYSHOC | Control |
| High-oil corn | 64.47 | ---- | 49.33 | ---- | 64.47 |
| High-lysine high-oil corn | ---- | 64.47 | ---- | 49.33 | ---- |
| Soybean meal (46.5% CP) | 20.92 | 20.92 | 36.50 | 36.50 | 20.92 |
| Spray-dried whey | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |
| Antibiotic[b] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Monocalcium phosphate | 1.47 | 1.47 | 1.20 | 1.20 | 1.47 |
| Limestone | .84 | .84 | .87 | .87 | .84 |
| Vitamin premix | .25 | .25 | .25 | .25 | .25 |
| Trace mineral premix | .15 | .15 | .15 | .15 | .15 |
| Salt | .35 | .35 | .35 | .35 | .35 |
| L-Lysine•HCl | .08 | ---- | .06 | ---- | .31 |
| DL-Methionine | .08 | .08 | .02 | .02 | .08 |
| L-Tryptophan | .04 | .04 | ---- | ---- | .04 |
| L-Threonine | .11 | .11 | .01 | .01 | .11 |
| Cornstarch | .23 | .31 | .25 | .31 | .01 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

[a]All diets contained .75% total Ca and .70% total P and were formulated to be isolysinic within each lysine level based on determined lysine digestibility values from Exp. 1. The total lysine levels for the .80, .975, and 1.15% digestible lysine levels were: .98-.99, 1.15, and 1.38-1.40%, respectively. [b]Provided 50 g/ton carbadox.

**Table 4. Apparent Ileal Digestibility of Nutrients in Diets Containing Normal or High-Lysine, High-Oil Corn[a,b]**

| | High-Oil Corn Variety[c] | | |
|---|---|---|---|
| Apparent Ileal Digestibility, % | Normal | High-lysine | CV |
| DM | 82.5 | 84.7 | 4.54 |
| CP | 84.3 | 85.5 | 2.99 |
| Ash | 40.0 | 41.3 | 13.82 |
| GE | 83.8 | 85.8 | 4.29 |
| Amino acids: | | | |
| Arginine | 88.6 | 90.3 | 2.06 |
| Histidine | 89.9 | 91.3 | 2.28 |
| Isoleucine | 88.4 | 90.2 | 1.92 |
| Leucine | 92.8 | 93.4 | 1.60 |
| Lysine | 88.4 | 90.4 | 2.24 |
| Methionine | 93.5 | 94.6 | 1.27 |
| Phenylalanine | 90.6 | 91.4 | 1.96 |
| Threonine | 81.4 | 83.8 | 2.80 |
| Valine | 88.2 | 89.6 | 1.98 |
| Alanine | 87.1 | 89.3 | 3.17 |
| Aspartic acid | 85.8 | 88.4 | 2.53 |
| Cysteine | 76.8 | 78.7 | 4.82 |
| Glutamic acid | 91.4 | 93.0 | 2.03 |
| Glycine | 60.8 | 66.6 | 8.00 |
| Serine | 84.7 | 87.1 | 2.21 |
| Tyrosine | 87.5 | 89.2 | 2.73 |

[a]Values are means of four barrows used in a crossover design. The data were analyzed initially as a crossover design. The effect of period and/or pig was significant only for ash (pig, P=.03; period, P=.09). Thus, the data presented here were analyzed as a completely randomized design. [b]All diets contained 8.5% casein. [c]Diets did not differ (P>.10).

**Table 5. Performance of Pigs Fed Diets Containing Normal (HOC) or High-Lysine (HLYSHOC) High-oil Corn[a,b]**

| | Digestible Lysine Level, % | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | .80 | | 1.15 | | .975 | | Probability Values | | | |
| Item, | HOC | HLYSHOC | HOC | HLYSHOC | Control | CV | Lysine | Corn | Lysine×Corn | Contrast[c] |
| ADG, lb | .80 | .73 | .97 | .98 | .85 | 9.14 | .0001 | .39 | .44 | .17 |
| ADFI, lb | 1.22 | 1.17 | 1.21 | 1.25 | 1.24 | 9.28 | .42 | .77 | .56 | .57 |
| F/G | 1.53 | 1.60 | 1.25 | 1.28 | 1.47 | 7.45 | .0001 | .43 | .61 | .15 |

[a]Values are means of four pigs per pen and five replicate pens per treatment. Pigs averaged 18.39 lb BW initially (d 10 postweaning) and 26.96 lb BW at the conclusion of the trial 10 d later.
[b]Within each lysine level, diets are identical except that L-lysine•HCl was added to the HOC diets to make them isolysinic. The .975% digestible lysine diet is identical to the .80% digestible lysine HOC diet, except that only additional L-lysine•HCl was added.
[c]Contrast refers to the comparison of the .975% digestible lysine diet to the average of the two .80% digestible lysine diets.

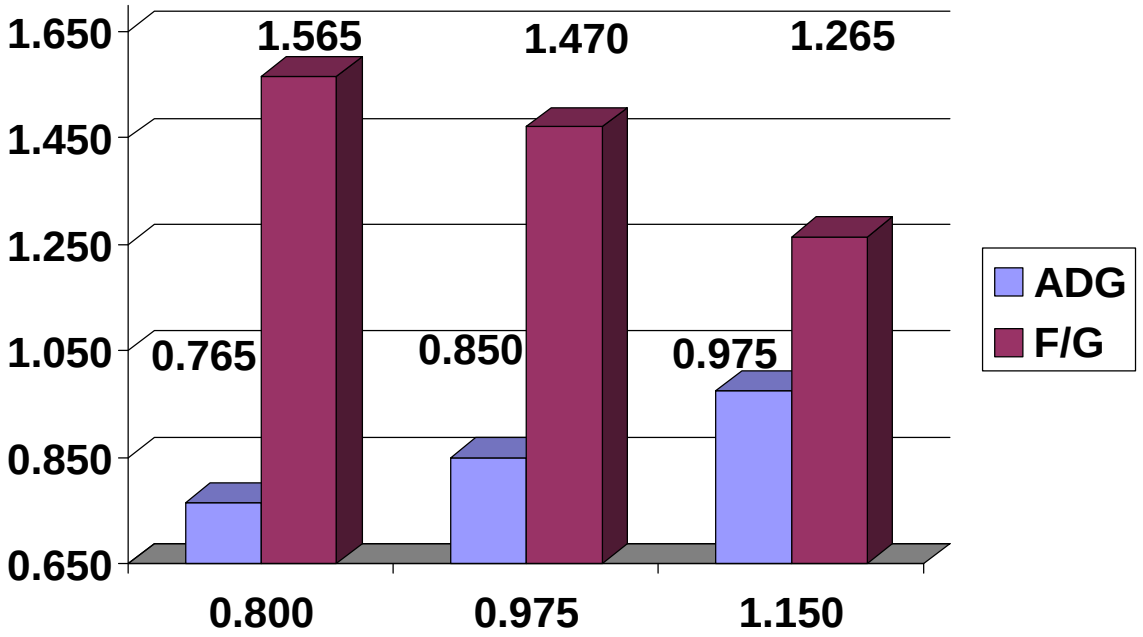



**Figure 1. Main Effects of Increasing Dietary Lysine on ADG and F/G of SEW Pigs.**

# EFFECTS OF EXOTIC SOYBEAN GENOTYPE ON GROWTH PERFORMANCE, NUTRIENT DIGESTIBILITY, AND CARCASS TRAITS IN FINISHING PIGS [1]

*H. Cao, J. D. Hancock, R. H. Hines, W. T. Schapaugh [2], T. L. Gugle, D. H. Kropf, C. A. Moloney, J. M. Jiang, J. Z. Cheng, and J. S. Park*

## Summary

Compared to a corn-soybean meal control, added-fat from tallow, soybean oil, and dry-extruded whole soybeans (DEWS) improved ADG, F/G, and digestibility of DM and N. Feeding tallow increased belly firmness but also increased backfat thickness compared to diets with soy oil and DEWS. Comparisons among soybean genotypes indicated that high oleic acid soybeans supported greater growth performance than soybeans with high palmitic acid content. However, soybean genotype had no effect on carcass or meat quality measurements.

(Key Words: Extrusion, Soybeans, Carcass, Finishing Pigs.**)**

## Introduction

Genetic modification of soybeans offers the opportunity to change nutritional (such as amino acids) and chemical (such as fatty acids) compositions. These changes could have direct effects on carcass characteristics in pigs, because finishing pigs fed extruded soybeans yield pork with an increased unsaturated:saturated fatty acid ratio. Therefore, we designed an experiment to determine the effects of soybean genotypes with modified fatty acid composition on growth performance, nutrient digestibility, and carcass traits in finishing pigs.

## Procedures

A total of 70 crossbred pigs (average initial BW of 145 lb) was used in a 47-d growth assay. The pigs were blocked by weight and allotted to pens (two pigs/pen and five pens/trt) based on sex and ancestry. The pigs were housed in an environmentally controlled building with a totally slatted floor. Each pen had a nipple waterer and a self-feeder to provide the pigs with ad libitum access to feed and water. Treatments were: 1) control, no added fat; 2) tallow; 3) soy oil; 4) mill run soybeans; 5) low linoleic acid soybeans; 6) high palmitic acid soybeans; and 7) high oleic acid soybeans. The mill run soybeans were purchased at the Manhattan Coop elevator. The low linoleic acid (3.4 vs 8.0% in commercial soybeans) and high palmitic acid (19 vs 10% in commercial soybeans) soybeans were grown at KSU, and the high oleic acid soybeans (85 vs 25% in commercial soybeans) were supplied courtesy of Dupont Quality Grains.

To prepare the soybeans for use in our diets, they were coarsely-rolled and then extruded in an Insta-Pro® dry-extruder. The target barrel temperature was 300°F. However, only 280°F was achieved. After extrusion, the dry-extruded whole soybeans (DEWS) were cooled and bagged for subsequent use in corn-based diets.

For d 0 to 25, the control diet (no added fat) was formulated to .9% lysine, .65% Ca,

[1]Appreciation is extended to the Kansas State Board of Agriculture and the Kansas Soybean Commission for funding this project and to Troy Lohroman and Dupont Quality Grains for the high oleic acid soybeans.

[2]Department of Agronomy.

and .55% P. The other diets were formulated to a lys:DE ratio of 3.6 g/Mcal with a dietary crude fat of 8.4%. The control diet for d 25 to 47 was formulated to .75% lysine. The other Phase II diets were formulated to a lys:DE ratio of 2.8 g/Mcal with a dietary crude fat of 7.3%.

Pig and feeder weights were taken at d 0, 25, and 47 of the growth assay. Feces samples were collected on d 46, dried, and ground for laboratory analyses. The pigs were killed in a commercial slaughter plant, and last rib backfat thickness and chilled carcass wt were recorded. Finally, belly firmness was evaluated by scoring from 1 (soft) to 3 (hard), and samples of loin muscle and fat were collected. Loin muscle and fat characteristics (loin area, water holding capacity, cooking loss, shear force of loin tissue, and backfat firmness) were evaluated according to standard procedures recommended in the 1991 NPPC Handbook.

Growth and carcass data were analyzed as a randomized complete block design using the GLM procedure of SAS. Pen was the experiment unit, and orthogonal comparisons were used to separate treatment means. Contrasts were: 1) no-added-fat control vs others; 2) tallow vs soy oil & DEWS; 3) soy oil vs DEWS; 4 mill run DEWS vs modified DEWS; 5) unsaturated (low linoleic acid) DEWS vs saturated (high palmitic and high oleic acid) DEWS; and 6) high palmitic acid DEWS vs high linoleic acid DEWS.

## Results and Discussion

Urease activity of the soybean preparations was below .4, and protein dispersible index ranged from 18 to 28% (Table 2). Trypsin inhibitor activity ranged from 7 to 18 mg/g. These laboratory measurements were greater than suggested values (i.e., .02 to .2 for urease activity and <4 mg/g for TI activity). Thus, the processing temperature of 280°F was less than desirable.

Results for growth performance of the pigs (Table 3) show that added fat (as tallow, soy oil, and DEWS) improved overall ADG ($P<.08$) and F/G ($P<.01$) and digestibilities of DM and N ($P<.01$). Pigs fed tallow were more efficient ($P<.04$) than pigs fed the various forms of soy oil (as free oil or DEWS) for d 0 to 25. However, the effect was not present for d 25 to 47 or overall, and the soy oil treatments tended to have greater digestibility of N ($P<.09$) than tallow diets.

Pigs fed soy oil had greater ($P<.02$) ADG (for d 0 to 25) and greater digestibilities of DM and N ($P<.03$) than pigs fed DEWS. These responses probably were related to the low processing temperature of 280°F achieved while processing the DEWS. However, even with the relatively high residual TI activity in the DEWS (8 to 18 mg/g), overall ADG and F/G were not different ($P>.15$) for pigs fed soy oil vs DEWS.

Comparisons among the DEWS sources suggested few difference, except that growth performance of pigs fed high oleic acid soybeans was consistently superior to growth performance of pigs fed soybeans with high palmitic acid content. However, this effect could be related to a difference in TI content of the end products (7 mg/g for high oleic acid DEWS and 12 mg/g for high palmitic acid DEWS) and not necessarily to a difference in fatty acid composition.

In terms of carcass traits, pigs fed tallow had increased belly firmness score ($P<.07$) but also increased backfat thickness ($P<.02$). However, tallow did not improve fat firmness when determined with an Instron Press ($P>.15$). No differences occurred among pigs fed the various soybean genotypes for belly firmness, loin muscle characteristics, or backfat characteristics ($P>.15$).

In conclusions, adding fat (as tallow, soy oil, or DEWS) to corn-based diets improved ADG and F/G. Tallow (our most saturated fat source) increased belly firmness score but not fat firmness when measured on an Instron Press. Finally, comparisons among DEW mill-run soybeans and soybeans with modified fatty acid composition suggested few effects on carcass fat and meat characteristics.

**Table 1. Compositions of Basal Diets**

| | Day 0 to 25[a] | | | | | | | Day 25 to 47[b] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ingredients, % | Control | Tallow | Soy oil | Mill run | Low lino | High palm | High oleic | Control | Tallow | Soy oil | Mil run | Low lino | High palm | High oleic |
| Corn | 74.85 | 64.74 | 64.74 | 64.74 | 64.74 | 64.74 | 64.74 | 80.03 | 72.19 | 72.19 | 72.19 | 72.19 | 72.19 | 72.19 |
| Soybean meal | 22.56 | 22.1 | 22.1 | - | - | - | - | 17.29 | 14.86 | 14.86 | - | - | - | - |
| Extruded soy | - | - | - | 29.88 | 29.93 | 32.65 | 30.98 | - | - | - | 22.99 | 23.03 | 25.12 | 23.83 |
| Soy oil | - | - | 5.9 | - | - | - | - | - | - | 5.4 | - | - | - | - |
| Tallow | - | 5.9 | - | - | - | - | | - | 5.4 | - | - | - | - | |
| Starch | - | 4.4 | 4.36 | 2.61 | 2.56 | - | 1.58 | - | 4.56 | 4.56 | 2.03 | 2.00 | - | 1.23 |
| Lysine HCL | .043 | .13 | .13 | .12 | .12 | .04 | .09 | .038 | .005 | .005 | .095 | .094 | .034 | .071 |
| DL-methionine | - | .04 | .037 | .044 | .044 | .016 | .033 | - | .04 | .037 | -- | -- | .016 | .033 |
| Monocalcium phosphate | .84 | 1.06 | 1.06 | .89 | .89 | .82 | .86 | .71 | .92 | .92 | .75 | .75 | .69 | .73 |
| Limestone | 1.01 | .95 | .95 | 1.0 | 1.00 | 1.02 | 1.01 | .99 | .94 | .94 | .98 | .98 | 1.00 | .99 |
| Salt | .35 | .36 | .36 | .36 | .36 | .36 | .36 | .35 | .36 | .36 | .36 | .36 | .36 | .36 |
| Trace minerals | .10 | .103 | .103 | .103 | .103 | .103 | .103 | .103 | .103 | .103 | .103 | .103 | .103 | .103 |
| Vitamin premix | .125 | .129 | .129 | .129 | .129 | .129 | .129 | .125 | .129 | .129 | .129 | .129 | .129 | .129 |
| Chromic oxide[c] | -- | -- | -- | -- | -- | -- | -- | .25 | .25 | .25 | .25 | .25 | .25 | .25 |
| Antibiotics [d] | .125 | .125 | .125 | .125 | .125 | .125 | .125 | .125 | .125 | .125 | .125 | .125 | .125 | .125 |

[a]The control diet for d 0 to 25 was formulated to .9% lysine, .65% Ca, and .55% P, and the other diets to a lys: DE ratio of 3.6 g/Mcal (crude fat was 8.4%).
[b]The control diet for d 25 to 47 was formulated to .75% lysine, .6% Ca, and .5% P, and the other diets to a lys: DE ratio of 2.8 g/Mcal (crude fat was 7.3%).
[c]As a indigestible marker.
[d]Supplied 50 g/ton of tylosin.

**Table 2. Processing Characteristics of Soybeans Varieties**

| Genotype | Mill Run | Low Linoleic | High Palmitic | High Oleic |
|---|---|---|---|---|
| GEI, kWh/ton[a] | 92.9 | 89.5 | 89.3 | 91.8 |
| SEI, kWh/ton[b] | 66.5 | 62.0 | 53.0 | 65.2 |
| PR, ton/hr [c] | .56 | .57 | 58.6 | .55 |
| Temperature, °F | 281 | 279 | 280 | 282 |
| TI of raw beans, mg/g [d] | 22.0 | 34.6 | 20.3 | 17.4 |
| TI of extruded beans, mg/g [d] | 10.5 | 12.7 | 11.8 | 6.9 |
| Urease, DpH [e] | .23 | .12 | .16 | .39 |
| PDI, % [f] | 27.1 | 26.4 | 23.4 | 18.1 |

[a]Gross energy input.
[b]Specific energy input.
[c]Production rate.
[d]Trypsin inhibitor activity.
[e]Urease activity.
[f]Protein dispersible index.

**Table 3. Effect of Soybean Genotype on Growth Performance and Nutrient Digestibility in Finishing Pigs[a]**

| Items | Control | Tallow | Soy Oil | Mill Run | Low Lino | High Palm | High Oleic | SE | Contrast [b] 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| d 0 to 25 | | | | | | | | | | | | | | |
| ADG, lb | 2.07 | 2.47 | 2.49 | 2.38 | 2.14 | 2.24 | 2.17 | .09 | .02 | .06 | .02 | .07 | -- | -- [c] |
| ADFI, lb | 6.16 | 5.91 | 6.25 | 6.13 | 5.39 | 6.03 | 5.52 | .20 | -- | -- | .04 | .05 | .12 | .09 |
| F/G | 2.98 | 2.39 | 2.51 | 2.58 | 2.51 | 2.67 | 2.56 | .03 | .001 | .04 | -- | -- | -- | -- |
| d 25 to 47 | | | | | | | | | | | | | | |
| ADG, lb | 1.71 | 1.92 | 1.76 | 1.69 | 1.84 | 1.84 | 2.00 | .17 | -- | -- | -- | -- | -- | .09 |
| ADFI, lb | 7.11 | 6.96 | 6.79 | 6.53 | 6.63 | 7.43 | 6.76 | .28 | -- | -- | -- | -- | -- | .10 |
| F/G | 4.15 | 3.64 | 3.88 | 3.91 | 3.57 | 4.64 | 3.41 | .05 | -- | -- | -- | -- | -- | .01 |
| Overall (d 0 to 47) | | | | | | | | | | | | | | |
| ADG, lb | 1.90 | 2.21 | 2.15 | 2.05 | 2.00 | 1.94 | 2.09 | .08 | .06 | .07 | -- | -- | -- | -- |
| ADFI, lb | 6.58 | 6.38 | 6.49 | 6.32 | 5.94 | 6.66 | 6.08 | .20 | -- | -- | -- | -- | .09 | .05 |
| F/G | 3.46 | 2.88 | 3.02 | 3.08 | 2.97 | 3.40 | 2.92 | .03 | .01 | -- | -- | -- | -- | .005 |
| Apparent nutrient digestibility, % | | | | | | | | | | | | | | |
| DM | 82.8 | 86.4 | 89.9 | 86.0 | 86.5 | 88.9 | 87.2 | .7 | .001 | .11 | .01 | .05 | .07 | .09 |
| N | 79.8 | 81.8 | 86.6 | 81.6 | 81.7 | 85.1 | 85.2 | 1.0 | .01 | .09 | .03 | .08 | .02 | -- |

[a]A total of 70 finishing pigs was used (two pigs/pen and five pens/trt) with an avg initial BW of 145 lb.

[b]Contrasts were: 1) no added fat control vs others; 2) tallow vs soy oil & DEWS; 3) soy oil vs DEWS; 4 mill run DEWS vs modified DEWS; 5) unsaturated (low linoleic acid) DEWS vs saturated (high palmitic and high oleic acid) DEWS; and 6) high palmitic acid DEWS vs high linoleic acid DEWS.

[c]Dashes indicate P>.15.

**Table 4. Effects of Soybean Genotype on Carcass Traits in Finishing Pigs[a]**

| Items | Control | Tallow | Oil | Mill Run | Low Lino | High Palm | High Oleic | SE | Contrasts [b] 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dressing, % | 76.1 | 75.9 | 75.7 | 75.8 | 74.1 | 75.1 | 76.1 | .8 | --[g] | -- | -- | -- | .06 | -- |
| Belly firmness [c] | 1.8 | 1.8 | 1.5 | 1.3 | 1.5 | 1.2 | 1.6 | .3 | .12 | .07 | -- | -- | -- | -- |
| Loin Muscle | | | | | | | | | | | | | | |
| Area, $in^2$ | 7.5 | 7.8 | 7.8 | 7.8 | 7.6 | 7.9 | 8.3 | .3 | -- | -- | -- | -- | -- | -- |
| Water holding capacity, g [d] | .38 | .40 | .48 | .36 | .37 | .25 | .34 | .1 | -- | -- | .08 | -- | -- | -- |
| Cooking loss, % | 24.7 | 24.0 | 25.6 | 25.6 | 24.8 | 24.7 | 25.3 | 2.0 | -- | -- | -- | -- | -- | -- |
| Tenderness, lb [e] | 1.9 | 2.1 | 2.1 | 2.3 | 2.1 | 2.3 | 2.5 | .1 | .04 | -- | -- | -- | -- | -- |
| Backfat | | | | | | | | | | | | | | |
| Thickness, in | 1.18 | 1.22 | 1.14 | 1.10 | 1.06 | 1.18 | 1.10 | .03 | -- | .04 | -- | -- | -- | -- |
| Firmness, lb [f] | 120.3 | 106.7 | 109.4 | 113.1 | 109.4 | 116.7 | 122.6 | 11.4 | -- | -- | -- | -- | -- | -- |

[a]A total of 70 finishing pigs was used (two pigs/pen and five pens/trt) with an avg initial BW of 145 lb.
[b]Contrasts were: 1) no fat control vs others; 2) tallow vs soy oil & DEWS; 3) soy oil vs DEWS; 4) mill run DEWS vs modified DEWS; 5) unsaturated (low linoleic acid) DEWS vs saturated (high palmitic and high oleic acid) DEWS; and 6) high palmitic acid vs high linoleic acid DEWS.
[c]Belly firmness scored from 1(soft) to 3 (hard ).
[d]Water holding capacity was grams of water loss from a cubic inch of muscle tissue during 24 hrs in a closed container.
[e]Warner-Bratzler method, Universal Instron Testing Machine.
[f] Compression test, Universal Instron Press Testing Machine.
[g]Dashes indicate P>.15.

# EFFECTS OF INCREASING TOTAL SULFUR AMINO ACID:LYSINE RATIO ON GROWTH PERFORMANCE OF 25 TO 50 LB PIGS

*M. De La Llata, M. D. Tokach [1], R. D. Goodband, J. L. Nelssen, S. S. Dritz [2], P. R. O'Quinn, J. C. Woodworth, and S. A. Moser*

## Summary

Three hundred and fifty pigs were used in a 27-d growth study to determine the appropriate total sulfur amino acid:lysine ratio for 25 to 50 lb pigs. Pigs were blocked by weight (initially 22.5 lb) and allotted to one of 10 treatments arranged in a 2 × 5 factorial with two levels of total dietary lysine (.95 and 1.25%) and five total sulfur amino acid ratios (.45, .50, .55, .60, and .65% of total lysine). Increasing total lysine from .95 to 1.25% increased ADG and improved F/G. Increasing the total sulfur amino acid:lysine ratio did not affect ADG but improved F/G. These results indicate that the optimal total sulfur amino acid:lysine ratio for the 25 to 50 lb pig is not greater than 55%.

(Key Words: Methionine, Lysine, Nursery Pigs.)

## Introduction

Some controversy exists concerning the optimal total sulfur amino acid:lysine ratio for swine diets. The University of Illinois has suggested that the methionine requirement should be 30% of lysine for pigs of all weights. They also suggest that the cystine requirement increases from 30% of lysine for young pigs to 35% of lysine for late finishing pigs. Thus, the total sulfur amino acid:lysine ratio would increase from 60% for young pigs to 65% for late finishing pigs. Recent research at Kansas State has shown that the methionine:lysine requirement for pigs weighing less than 25 lb is 27.5% of lysine, and the total sulfur amino acid:lysine ratio is 55%. Other research at Kansas State and Louisiana State Universities has demonstrated that the total sulfur amino acid level needs to be only 50 to 55% of lysine for late finishing pigs. The total sulfur amino acid:lysine ratio commonly used by the swine industry for the late starter and early growing pig ranges from 50 to 60%. This range in values leads to wide variations in the amount of DL-methionine added to a sorghum or sorghum-soybean based diet. None of the prior research has been conducted to determine the optimal methionine:lysine ratio for the 25 to 50 lb pig. Therefore, the objective of this study was to determine the appropriate total sulfur amino acid:lysine ratio for pigs in this weight range.

## Procedures

Three hundred and fifty pigs were blocked by weight (initially 22.5 lb) and allotted to one of the 10 dietary treatments. There were five pigs per pen and seven replicate pens per treatment. The experimental diets consisted of a 2 × 5 factorial arrangement with two levels of total lysine (.95 and 1.25%) and five increasing levels of total sulfur amino acid:lysine ratios (45, 50, 55, 60 and 65%). Therefore, the total sulfur amino acid levels in the 0.95% lysine diets were .43, .48, .52, .57, and .62%. For the 1.25% lysine diets, the total sulfur amino acid levels were .56, .62, .68, .75, and .81%.

The dietary treatments within the same lysine level contained equal amounts of all the

[1]Northeast Area Extension Office, Manhattan, KS.
[2]Food Animal Health and Management Center.

ingredients except for DL-methionine additions. Crystalline amino acids were added to maintain identical ratios of all amino acids relative to lysine except for methionine.

All experimental diets were sorghum-soybean meal based (Table 1) and were fed in a meal form through the 27 d experiment. Pigs were housed in the Kansas State University Segregated Early-Weaning facility and allowed ad libitum access to food and water through a dry feeder and one nipple waterer per pen. The pigs were weighed and feed disappearance was measured on d 10, 21, and 27 to determine ADG, ADFI, and F/G.

Analysis of variance was used to analyze the data as a randomized complete block design with a 2 × 5 factorial arrangement using GLM procedures of SAS with linear and quadratic polynomial contrasts to determine the effects of increasing total sulfur amino acid:lysine ratio within a lysine level.

## Results and Discussion

Pigs fed the 1.25% lysine diets increased ADG and improved F/G (P<.01; Table 2) when compared to pigs fed .95% lysine for the overall experiment. Average daily gain and ADFI were not affected (P>.24), but F/G was improved (quadratic, P< .03) by increasing the total sulfur amino acid:lysine ratio. No lysine × methionine interactions were observed throughout the study.

The results from this experiment indicate that the total sulfur amino acid:lysine requirement for the 25 to 50 lb pig is not greater than 55%. These results agree with previous research at Kansas State University and Louisiana State University showing that the total-sulfur amino acid:lysine ratio requirements are 55% for pigs weighing less than 25 lb and from 50 to 55% for the late finishing pig.

The importance of determining the appropriate methionine:lysine ratio is that, as we increase or decrease the lysine level in the diet by increasing or decreasing soybean meal, the methionine:lysine and total sulfur amino acid:lysine ratios also change. By establishing the optimal ratio, we can balance the diets accordingly. Based on this research, we suggest that the optimal total sulfur amino acid:lysine ratio for the pig up to 50 lb is 55%.

**Table 1. Diet Composition**

| | .95% Lys | | | | | 1.25% Lys | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Met & Cys:Lysine ratio, % | | | | | Met & Cys:Lysine ratio, % | | | | |
| Ingredient, % | 45 | 50 | 55 | 60 | 65 | 45 | 50 | 55 | 60 | 65 |
| Sorghum | 78.55 | 78.50 | 78.45 | 78.41 | 78.36 | 66.56 | 66.50 | 66.44 | 66.38 | 66.31 |
| Soybean meal, 46.5% | 14.50 | 14.50 | 14.50 | 14.50 | 14.50 | 26.50 | 26.50 | 26.50 | 26.50 | 26.50 |
| Choice white grease | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Monocalcium phosphate | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 |
| Limestone | .90 | .90 | .90 | .90 | .90 | .90 | .90 | .90 | .90 | .90 |
| Salt | .35 | .35 | .35 | .35 | .35 | .35 | .35 | .35 | .35 | .35 |
| Vitamin premix | .25 | .25 | .25 | .25 | .25 | .25 | .25 | .25 | .25 | .25 |
| Trace mineral premix | .15 | .15 | .15 | .15 | .15 | .15 | .15 | .15 | .15 | .15 |
| Lysine HCl | .42 | .42 | .42 | .42 | .42 | .38 | .38 | .38 | .38 | .38 |
| DL-Methionine | -- | .05 | .10 | .14 | .19 | -- | .06 | .12 | .18 | .25 |
| L-Threonine | .17 | .17 | .17 | .17 | .17 | .20 | .20 | .20 | .20 | .20 |
| L-Tryptophan | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| Calculated analysis, % | | | | | | | | | | |
| Lysine | .95 | .95 | .95 | .95 | .95 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 |
| Methionine:lysine ratio | 23 | 28 | 33 | 38 | 43 | 22 | 27 | 32 | 37 | 42 |
| Met & Cys:lysine ratio | 45 | 50 | 55 | 60 | 65 | 45 | 50 | 55 | 60 | 65 |
| Threonine:lysine ratio | 69 | 69 | 69 | 69 | 69 | 70 | 70 | 70 | 70 | 70 |
| Met & Cys | .43 | .48 | .52 | .57 | .62 | .56 | .62 | .68 | .75 | .81 |
| Ca | .72 | .72 | .72 | .72 | .72 | .75 | .75 | .75 | .75 | .75 |
| P | .67 | .67 | .67 | .67 | .67 | .71 | .71 | .71 | .71 | .71 |

**Table 2. Influence of Increasing Total Sulfur AminoAcid:Lysine Ratios on the Growth Performance of 25 to 50 lb Pigs[a]**

| | .95% Total Lysine | | | | | 1.25% Total Lysine | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Met & Cys:Lysine ratio, % | | | | | Met & Cys:Lysine ratio, % | | | | | | Probability (P<) | | |
| Item | 45 | 50 | 55 | 60 | 65 | 45 | 50 | 55 | 60 | 65 | CV | Lys | Met | Lys × Met |
| Day 0 to 27 | | | | | | | | | | | | | | |
| ADG, lb | 1.04 | 1.11 | 1.06 | 1.05 | 1.08 | 1.29 | 1.33 | 1.33 | 1.38 | 1.36 | 6.1 | 0.01 | 0.24 | 0.35 |
| ADFI, lb | 2.09 | 2.19 | 2.05 | 2.08 | 2.07 | 2.24 | 2.14 | 2.06 | 2.17 | 2.17 | 6.4 | 0.06 | 0.24 | 0.35 |
| F/G[b,c] | 2.00 | 1.96 | 1.94 | 1.97 | 1.91 | 1.73 | 1.61 | 1.55 | 1.57 | 1.60 | 4.9 | 0.01 | 0.01 | 0.21 |

[a]Three hundred and fifty pigs (initially 22.5 lb) with five pigs per pen and seven replications (pens) per treatment.
[b]Linear effect of methionine:lysine ratio (P<.01).
[c]Quadratic effect of methionine:lysine ratio (P<.03).

*Swine Day 1998*

# EFFECTS OF AN ENTERIC DISEASE CHALLENGE ON GROWTH, NITROGEN RETENTION, AND IMMUNE STATUS INDICATORS IN GROWING PIGS

***J. A. Loughmiller, S. S. Dritz [1], M. D. Tokach [2], M. De La Llata, S. Moser, J. L. Nelssen, R. D. Goodband, R. E. Musser, and R. D. Stott***

## Summary

Thirty-five growing pigs (initially 65 ± 2 lb) were used in a metabolism study to determine the effects of a single enteric disease challenge on N retention, growth performance, and blood immunological variables. Twenty-one pigs were challenged with *Salmonella typhimurium*, and six pigs were assigned to an ad libitum-fed, nonchallenged control group. Eight additional nonchallenged pigs were pair-fed the feed intake of an *S. typhimurium* challenged counterpart. There were five 4 d collection periods (d 4 to 7, d 8 to 11, d 12 to 15, d 16 to 19, and d 22 to 25), with the *S. typhimurium* challenge occurring on d 8. Serum haptoglobin concentration increased in the disease-challenged pigs, when compared to both nonchallenged treatments Growth performance and N retention were decreased temporarily during the immune challenge period but recovered to levels similar to those of nonchallenged control pigs by the end of the experiment on d 25. These results suggest that a single acute disease challenge may not be accompanied by large compromises in growth performance and lean growth rate.

(Key Words: Growing Pigs, Nitrogen Retention, Disease Challenge.)

## Introduction

Chronic disease challenges that restrict lean growth potential have been minimized by wide-scale adoption of all-in/all-out, multi-site production, and segregated early weaning. However, short-duration, acute disease challenges still occur. An acute disease challenge usually results from a pathogen infecting immune-naive groups of pigs. The pathogen spreads rapidly within the group, and within a short period, immunity develops and performance partially recovers. Although lean growth rate has been improved dramatically in high-health production systems, acute disease challenges appear to be responsible for a large majority of the variation in lean growth rate between groups of pigs and among individuals within a group of pigs.

Research at Iowa State University and elsewhere has established that protein metabolism is influenced negatively in immune-challenged pigs. Those experiments were designed to characterize the effects of chronic immune challenges typical in continuous-flow production systems. These chronic disease challenges may not be reflective of typical disease processes observed in most progressive swine production systems. Our objective was to characterize the effects of an acute disease challenge in pigs by measuring changes in protein metabolism using nitrogen (N) retention techniques. Furthermore, we wanted to characterize the change in several plasma immune status indicators and a growth mediator before, during, and after an acute disease challenge.

## Procedures

The experimental protocol used in this study was approved by the KSU Animal Care

[1]Food Animal Health and Management Center.
[2]Northeast Area Extension Office, Manhattan, KS.

and Use Committee. Thirty-five non-littermate high-health barrows (PIC C22 × L326; initially 65 ± 2 lb) obtained from a herd without clinical evidence of a *Salmonella typhimurium* infection were blocked by weight and time and allotted to one of three experimental treatments. Pigs were selected in groups of five or six from the same farrowing group and were assigned randomly to either the *Salmonella* challenge or control group. Within the control group, pigs were assigned randomly to receive ad libitum feed intake or to be pair-fed the previous day's feed intake of an assigned *Salmonella*-challenged pig. Once the pair-fed control pigs were allotted to a *Salmonella*-challenged pig, they were fed the feed intake of that same pig throughout all periods. The pair-feeding was performed to elicit the responses independent of feed intake. Water was supplied at 2.5:1 ratio with feed on a wt:wt basis. All pigs were fed and watered twice daily at 6:30 a.m. and 6:30 p.m. Orts were collected just prior to the next feeding. Because of the expected greater variation in performance of the *S. typhimurium* group, 21 pigs were assigned to the *Salmonella* group, with 8 pigs control pair-fed, and 6 control ad libitum fed pigs. All pigs were fed a common corn-soybean meal diet formulated to 1.15% total lysine, with no synthetic amino acids, added fat, or antibiotics (Table 1). There were five 4-d collection periods (d 4 to 7, d 8 to 11, d12 to 15, d 16 to 19, and d 22 to 25), with the *S. typhimurium* challenge occurring on d 8. These included a prechallenge period, a challenge period, two recovery periods, and a postchallenge period. The later was selected to be at least 14 d postchallenge. Pigs assigned to the *Salmonella* challenge treatment were inoculated intragastrically by oral catheter with $10^9$ cfu *S. typhimurium.*

All pigs were housed in two similar environmentally controlled rooms based upon health status and were kept in adjustable individual stainless steel metabolism cages (5 ft × 2 ft) that allowed separate collection of feces and urine. The marker to marker method (.5% ferric oxide in the first and eighth subsequent meal) was used to determine the beginning and end of feces collection for a period. Feces were collected twice daily and stored at 20° F. At the end of each period, feces were autoclaved to kill pathogenic activity before being homogenized and subsampled. The fecal subsamples then were analyzed for N and DM. Urine was collected daily in polypropylene bottles containing 75 mL of 6 *N* HCl. Ten percent of the daily urine volume was subsampled and stored at 20° F until laboratory analysis. Urine was centrifuged at 2000 g to remove particulate matter and then was analyzed for N and DM. Feed samples were ground through a 1mm screen before analysis of N and DM. Feed, urine, and feces were analyzed for N on an as-is basis to minimize any loss of gaseous ammonia before analysis.

**Table 1. Diet Composition**

| Ingredient | % |
|---|---|
| Corn | 64.04 |
| Soybean meal, 46.5% CP | 32.89 |
| Monocalcium phosphate | 1.22 |
| Limestone | 1.10 |
| Salt | .35 |
| Vitamin premix | .25 |
| Trace mineral premix | .15 |

[a]Diet was formulated to contain 1.15% lysine, .75% Ca and .65% P.

Blood samples were drawn via jugular venapuncture using heparinized, serum, and EDTA vacuum tubes on d 5, 9, 13, 17, and 23 at least 2 h postprandial to measure the time course change in segmented neutrophils, monocytes, plasma concentrations of insulin-like growth factor-I (IGF-I), and serum haptogolobin concentrations.

All data were analyzed as a randomized incomplete block design using a mixed model procedure with repeated measures. Pigs were blocked by initial weight and time, with individual pig as the experimental unit. Periodic samples by pig were used for the repeated measures. Linear and quadratic polynomial contrasts were used to determine the effects of *Salmonella* challenge over time on all response criteria.

## Results and Discussion

A disease status by time interaction (P<.05) was observed for ADG (Table 2). The interaction was a result of decreased ADG (P<.01) from d 8 to 11 for the *S. typhimurium*-challenged pigs versus the ad libitum-fed control pigs. The pair-fed control pigs tended to have intermediate ADG compared to both of the other groups (P<.07). A tendency for a disease status by time interaction was observed for ADFI (P<.11), primarily as a result of changes in d 8 to 11 ADFI between the *S. typhimurium*-challenged pigs and the ad libitum-fed control pigs. The d 8 to 25 ADFIs were 4.08, 4.18, and 3.83 lb for the *S. typhimurium* challenged pigs, ad libitum-fed controls, and the pair-fed control pigs, respectively. From d 4 to 7, ADFI was lower for the pair-fed controls when compared to *S. typhimurium*-challenged pigs (P<.05). This initial difference in ADFI likely was a result of the time lag in pair-fed pigs' intake, which was equalized to the *S. typhimurium*-challenged pigs' intake 24 h later. Feed efficiency (G/F) was also worse for *S. typhimurium*-challenged pigs compared to pair-fed controls from d 8 to 11 (P<.05). In general, differences in growth performance were observed only during the d 8 to 11 challenge period.

**Table 2. Effects of *S. typhimurium* Challenge and Feeding Regimen on Growth Performance in 65 to 125 lb Pigs[a]**

| | *S. typhimurium* | Nonchallenged | | Probability (P <) | | |
|---|---|---|---|---|---|---|
| | Ad libitum | Ad libitum | Pair-fed | | | |
| Item[b] | (Trt 1) | (Trt 2) | (Trt3) | 1 vs. 2 | 1 vs. 3 | 2 vs. 3 |
| Pigs per treatment | 21 | 6 | 8 | | | |
| Day 4 to 7 | | | | | | |
| ADG, lb | 2.54 ± .22 | 2.25 ± .39 | 2.62 ± .34 | .52 | .85 | .48 |
| ADFI, lb | 3.52 ± .23 | 3.01 ± .31 | 3.02 ± .28 | .06 | .04 | .96 |
| G/F | .73 ± .10 | .81 ± .18 | .91 ± .16 | .70 | .31 | .65 |
| Day 8 to 11 | | | | | | |
| ADG, lb | 1.36 ± .22 | 3.05 ± .39 | 2.09 ± .34 | .01 | .07 | .06 |
| ADFI, lb | 2.92 ± .23 | 3.61 ± .31 | 3.07 ± .28 | .01 | .53 | .08 |
| G/F | .20 ± .10 | .84 ± .18 | .62 ± .16 | .01 | .02 | .36 |
| Day 12 to 15 | | | | | | |
| ADG, lb | 2.42 ± .22 | 1.93 ± .39 | 2.48 ± .34 | .26 | .88 | .28 |
| ADFI, lb | 4.00 ± .23 | 4.17 ± .31 | 3.64 ± .28 | .53 | .14 | .09 |
| G/F | .62 ± .10 | .48 ± .18 | .74 ± .16 | .49 | .51 | .27 |
| Day 16 to 19 | | | | | | |
| ADG, lb | 2.23 ± .22 | 2.34 ± .39 | 2.42 ± .34 | .80 | .63 | .87 |
| ADFI, lb | 4.30 ± .23 | 4.20 ± .31 | 4.11 ± .28 | .70 | .42 | .76 |
| G/F | .53 ± .10 | .55 ± .18 | .59 ± .16 | .90 | .73 | .87 |
| Day 22 to 25 | | | | | | |
| ADG, lb | 2.35 ± .22 | 2.48 ± .39 | 2.06 ± .34 | .77 | .47 | .41 |
| ADFI, lb | 4.99 ± .24 | 5.02 ± .31 | 4.71 ± .28 | .92 | .25 | .32 |
| G/F | .48 ± .10 | .50 ± .18 | .45 ± .16 | .91 | .89 | .84 |
| Day 8 to 25 | | | | | | |
| ADG, lb | 2.11 ± .16 | 2.43 ± .24 | 2.24 ± .22 | .21 | .58 | .49 |
| ADFI, lb | 4.08 ± .23 | 4.18 ± .28 | 3.83 ± .27 | .68 | .22 | .15 |
| G/F | .49 ± .06 | .58 ± .11 | .59 ± .09 | .44 | .34 | .94 |

[a]Thirty five pigs were used in a randomized incomplete block design with individual pig as the experimental unit. *S. typhimurium* challenge occurred on d 8. Effects were analyzed using a mixed model with repeated measures. Feed efficiency is expressed as gain:feed (G/F) instead of feed:gain (F/G).

[b]A status × time interaction was observed for ADG (P<.05). Both linear and quadratic time effects (P<.05) were observed for ADFI. A linear time effect (P<.05) was observed for G/F.

A disease status by time interaction also was observed for DM (P<.05) and N (P<.06) digestibility (Table 3). The interaction for DM resulted from d 16 to 19 and d 22 to 25 DM digestibility being greater for *S. typhimurium*-challenged pigs when compared to control ad libitum-fed pigs (P<.05). Dry matter digestibility from d 12 to 25 was also greater for the *S. typhimurium*-challenged pigs versus the pair-fed controls (P<.10). As the pair-fed control pigs increased feed intake from d 12 to 15, they also had increased DM digestibility when compared to the ad libitum-fed control pigs (P<.03). This resulted in increased d 8 to 25 DM digestibility for the *S. typhimurium*-challenged pigs versus the ad libitum-fed control pigs (P<.05). Additionally, DM digestibility tended to be better for the pair-fed control pigs when compared to the ad libitum-fed control pigs from d 8 to 25 (P<.08). The differences in digestibility may have been due to improved metabolic efficiency and further indicate that compensatory gain occurred as ADFI increased for the *S. typhimurium*-challenged pigs during the recovery and postchallenge periods.

A disease status by time interaction was observed for fecal N and retained N (P<.05; Table 4). The interaction resulted from decreased N retention during the acute challenge period (d 8 to 11), indicating a reduction in lean growth rate for both pair-fed control and the *S. typhimurium*-challenged pigs as compared to the ad libitum-fed control pigs (Figure 1). The fecal N interaction was a result of changes in ADFI and increased digestibility from d 16 to 19 and d 8 to 25 for the *S. typhimurium*-challenged pigs, and the pair-fed control pigs compared to the ad libitum-fed control pigs (P<.05). Tendencies for differences in N intake, N retention, and fecal N (P<.10) between pair-fed and ad lib controls were results of decreases in the pair-fed pigs' ADFI from d 8 to 11. Nitrogen intake was similar across treatments (quadratic, P<.05), except for the tendency towards a reduction associated with d 8 to 11 ADFI for the *S. typhimurium*-challenged (P<.01) and pair-fed control pigs (P<.08) versus the ad libitum-fed controls. Similarly, urine N increased over time as a result of increased intake (quadratic, P<.05).

A tendency for a disease status by time interaction was observed for the percentage of N intake retained (P<.13; Table 5). From d 8 to 11, N retention efficiency, both as percentage of N intake and percentage of absorbed N, was worse for *S. typhimurium*-challenged pigs versus control ad libitum-fed pigs (P<.05), with intermediate efficiency for the pair-fed controls (P<.07). The d 8 to 11 N retention efficiency differences between treatments indicate that the change in protein metabolism for the *S. typhimurium*-challenged pigs was due to more than the effect of reduced ADFI and related reductions in N retention. The differences in d 8 to 11 N retention efficiency and feed utilization indicate two things. First, during the acute disease challenge, the *S. typhimurium*-challenged pigs were partitioning nutrients to the immune response and not to growth. Secondly, the poorer utilization by the *S. typhimurium*-challenged pigs versus pair-fed controls indicates that only part of the decreased growth performance and N retention was explained by decreased ADFI. The remainder of the lost metabolic efficiency was unique to the immune challenge and was likely due to the increased body heat from loss fever and short-term changes in gastrointestinal physiology associated with an acute enteric disease challenge.

A disease status by time interaction was observed for haptoglobin concentration (P<.05; Table 6). Day 9 and 13 haptoglobin levels were highest for the *S. typhimurium*-challenged pigs versus the ad libitum-fed control pigs (P<.05). Haptoglobin levels of pair-fed control pigs were intermediate to those of both other treatments and differed from those of the *S. typhimurium*-challenged pigs on d 13 and d 17 (P<.05; P<.10, respectively). The haptoglobin response indicates that concentrations increased and then decreased for the challenge pigs during and after the challenge period, while remaining relatively flat for the pigs in both control treatments (Figure 2). This response is consistent with previous research indicating

that acute phase proteins increase in concentration with an increase in immunological activity.

Insulin-like growth factor-I concentration increased regardless of disease status from d 4 to 25 (linear, P<.05; Figure 3). By d 17, IGF-I levels were highest in the *S. typhimurium*-challenged pigs, and differed from those of the pair-fed controls on d 17 and the ad libitum-fed control pigs on d 23 (P<.05). A tendency for increased d 17 IGF-I levels was observed for the *S. typhimurium*-challenged pigs versus the ad libitum-fed control pigs (P<.10). The increased levels of IGF-I were concurrent with improvements in growth performance and N retention of the *S. typhimurium*-challenged pigs during the recovery and postchallenge periods.

A disease status by time interaction was observed for segmented neutrophils (P<.05). A numerical reduction in d 13 segmented neutrophils for the *S. typhimurium*-challenged pigs was observed (P>.10). By d 17, however, segmented neutrophils increased for the *S. typhimurium*-challenged pigs when compared to both control treatments (P<.05). This response is consistent with previous research indicating that the segmented neutrophil count will decrease during a disease challenge and subsequently increase during recovery and postchallenge periods.

Monocyte concentration tended to decrease regardless of status from d 4 to 25, with the greatest decrease in monocyte concentration occurring after d 13 (linear, P<.09). A tendency for increased levels of d 17 monocytes was observed for the *S. typhimurium*-challenged pigs versus the ad libitum-fed control pigs (P<.10).

A major portion of the differences in growth performance and N retention between *S. typhimurium*-challenged pigs and ad libitum-fed control pigs was due to feed intake differences. However, the differences between the pair-fed controls and ad libitum-fed controls indicate the differences in protein metabolism related to feed intake. The additional decreases in growth performance and N retention for the *S. typhimurium*-challenged pigs were due to changes in metabolic processes in response to the disease challenge. The changes in blood growth and immune parameters are also consistent with the results observed for growth performance and N retention.

The results of this experiment are consistent with previous studies, indicating that protein metabolism, as indicated by N retention, and growth performance are affected negatively by immune activation. They also indicate that an oral dose of $10^9$ cfm of *S. typhimurium* is sufficient to produce an acute immune response. These results further indicate that most of the effects from an acute enteric immune challenge on protein metabolism are due to decreased feed intake. In addition, factors unique to the acute immune response, such as increased body heat loss from fever, and short-term changes in gastrointestinal physiology, cause further short-term reduction in performance.

Perhaps the most surprising result of this experiment is the lack of long-term changes in N retention and growth performance. In addition, the compensatory growth performance and N retention driven by elevated IGF-I levels indicate that few long term effects will be associated with acute immune activity. In comparison, our results are consistent with research using a noninfectious immune challenge in chickens. A lack of long term growth reduction and compensatory gain were reported consistently.

Based upon field experience, pigs subjected to an enteric disease immune challenge have shown longer term reductions in lean growth rate. This decrease in overall performance is due to the interplay of other factors outside of the acute disease challenge. In contrast to typical field conditions, the pigs used in this experiment were maintained in a near ideal environment, with minimal outside stress and a similar infectious dose. The lack of additional stressors such as social interaction with penmates, reinfection from other pigs, and competition for feed and

water likely contributed to the rapid recovery in this experiment. The results of this experiment indicate that a single acute disease outbreak may not be accompanied by large compromises in growth performance and lean growth rate. However, short-term changes in lean growth rate are due to both feed intake reductions and repartitioning nutrients to the immune response.

**Table 3. Effects of *S. typhimurium* Challenge and Feeding Regimen on Dry Matter and Nitrogen Digestibility in 65 to 125 lb Pigs[a]**

| | *S. typhimurium* | Nonchallenged | | | | |
|---|---|---|---|---|---|---|
| | Ad libitum | Ad libitum | Pair-fed | Probability (P <) | | |
| Digestibility[b], % | (Trt 1) | (Trt 2) | (Trt 3) | 1 vs. 2 | 1 vs. 3 | 2 vs. 3 |
| Day 4 to 7 | | | | | | |
| Dry matter | 87.5 ± .37 | 87.2 ± .77 | 87.1 ± .64 | .72 | .55 | .89 |
| Nitrogen | 90.4 ± 1.26 | 89.4 ± 2.68 | 89.8 ± 2.20 | .74 | .81 | .92 |
| Day 8 to 11 | | | | | | |
| Dry matter | 86.3 ± .36 | 86.4 ± .64 | 86.3 ± .55 | .83 | .98 | .84 |
| Nitrogen | 83.8 ± 1.20 | 88.1 ± 2.19 | 89.2 ± 1.91 | .09 | .02 | .68 |
| Day 12 to 15 | | | | | | |
| Dry matter | 86.7 ± .36 | 86.0 ± .64 | 87.8 ± .55 | .27 | .10 | .03 |
| Nitrogen | 89.5 ± 1.20 | 88.2 ± 2.19 | 90.0 ± 1.91 | .58 | .85 | .53 |
| Day 16 to 19 | | | | | | |
| Dry matter | 87.6 ± .36 | 85.0 ± .64 | 85.9 ± .55 | .01 | .02 | .27 |
| Nitrogen | 89.5 ± 1.20 | 84.2 ± 2.19 | 85.9 ± 1.91 | .04 | .11 | .56 |
| Day 22 to 25 | | | | | | |
| Dry matter | 88.0 ± .36 | 86.5 ± .64 | 86.9 ± .55 | .04 | .10 | .63 |
| Nitrogen | 89.7 ± 1.20 | 85.7 ± 2.19 | 86.7 ± 1.91 | .11 | .28 | .75 |
| Day 8 to 25 | | | | | | |
| Dry matter | 87.1 ± .19 | 86.1 ± .36 | 86.8 ± .31 | .02 | .45 | .08 |
| Nitrogen | 88.1 ± .71 | 86.6 ± 1.25 | 88.0 ± 1.09 | .28 | .93 | .38 |

[a]Thirty five pigs were used in a randomized incomplete block design with individual pig as the experimental unit. *S. typhimurium* challenge occurred on d 8. Effects were analyzed using a mixed model with repeated measures.

[b]A status × time interaction was observed for DM digestibility (P<.05) and N digestibility (P<.06).

**Table 4. Effect of *S. typhimurium* Challenge and Feeding Regimen on Nitrogen Balance in 65 to 125 lb Pigs[a]**

| | *S. typhimurium* | Nonchallenged | | | | |
|---|---|---|---|---|---|---|
| | Ad libitum | Ad-libitum | Pair-fed | Probability (P <) | | |
| Item[b], g/d | (Trt 1) | (Trt 2) | (Trt 3) | 1 vs. 2 | 1 vs. 3 | 2 vs. 3 |
| Day 4 to 7 | | | | | | |
| N intake | 50.7 ± 3.6 | 43.6 ± 4.6 | 44.6 ± 4.3 | .07 | .08 | .83 |
| Fecal N | 5.4 ± .72 | 5.3 ± 1.1 | 5.0 ± .9 | .86 | .64 | .85 |
| Urine N | 15.9 ± 2.3 | 13.6 ± 2.9 | 14.1 ± 2.7 | .36 | .41 | .87 |
| N retained | 30.7 ± 1.9 | 25.4 ± 3.7 | 25.5 ± 2.7 | .18 | .13 | .98 |
| Day 8 to 11 | | | | | | |
| N intake | 42.4 ± 3.6 | 52.3 ± 4.6 | 44.5 ± 4.3 | .01 | .54 | .08 |
| Fecal N | 5.9 ± .71 | 5.8 ± .9 | 4.5 ± .9 | .90 | .07 | .19 |
| Urine N | 17.0 ± 2.3 | 16.2 ± 2.9 | 16.7 ± 2.7 | .71 | .86 | .85 |
| N retained | 19.6 ± 1.9 | 30.1 ± 3.1 | 23.2 ± 2.7 | .002 | .23 | .07 |
| Day 12 to 15 | | | | | | |
| N intake | 58.0 ± 3.6 | 60.5 ± 4.6 | 52.9 ± 4.3 | .51 | .15 | .09 |
| Fecal N | 6.3 ± .71 | 6.8 ± .9 | 5.2 ± .9 | .51 | .15 | .09 |
| Urine N | 18.9 ± 2.3 | 18.9 ± 2.9 | 16.4 ± 2.7 | .98 | .26 | .36 |
| N retained | 33.0 ± 1.9 | 34.5 ± 3.1 | 31.1 ± 2.7 | .65 | .54 | .38 |
| Day 16 to 19 | | | | | | |
| N intake | 62.3 ± 3.6 | 60.9 ± 4.6 | 59.6 ± 4.3 | .72 | .44 | .76 |
| Fecal N | 6.7 ± .71 | 9.2 ± .9 | 8.3 ± .9 | .005 | .04 | .35 |
| Urine N | 22.0 ± 2.3 | 23.1 ± 2.9 | 22.1 ± 2.7 | .65 | .94 | .73 |
| N retained | 33.7 ± 1.9 | 28.4 ± 3.1 | 29.1 ± 2.7 | .11 | .12 | .87 |
| Day 22 to 25 | | | | | | |
| N intake | 72.1 ± 3.6 | 72.8 ± 4.6 | 68.3 ± 4.3 | .87 | .28 | .31 |
| Fecal N | 7.7 ± .72 | 9.9 ± .9 | 8.8 ± .9 | .008 | .13 | .25 |
| Urine N | 28.8 ± 2.3 | 32.1 ± 2.9 | 28.7 ± 2.7 | .18 | .97 | .22 |
| N retained | 35.8 ± 1.9 | 30.5 ± 3.1 | 30.6 ± 2.7 | .12 | .09 | .98 |
| Day 8 to 25 | | | | | | |
| N intake | 56.9 ± 3.3 | 58.0 ± 3.9 | 54.0 ± 3.7 | .70 | .29 | .20 |
| Fecal N | 6.4 ± .67 | 7.5 ± .76 | 6.4 ± .73 | .03 | .97 | .05 |
| Urine N | 20.4 ± 2.1 | 20.8 ± 2.4 | 19.6 ± 2.3 | .82 | .61 | .51 |
| N retained | 30.5 ± 1.3 | 30.1 ± 1.9 | 28.1 ± 1.7 | .83 | .16 | .34 |

[a]Thirty five pigs were used in a randomized incomplete block design with individual pig as the experimental unit. *S. typhimurium* challenge occurred on d 8. Effects were analyzed using a mixed model with repeated measures.

[b]Status × time interactions were observed for both fecal N and N retained (P<.05). Linear and quadratic time effects (P<.05) were observed for N intake, and urine N.

**Table 5. Effect of *S. typhimurium* Challenge and Feeding Regimen on N Retention Efficiency in 65 to 125 lb Pigs[a]**

| N Retention Efficiency, % | *S. typhimurium* Ad libitum (Trt 1) | Nonchallenged Ad libitum (Trt 2) | Nonchallenged Pair-fed (Trt 3) | Probability (P <) 1 vs. 2 | 1 vs. 3 | 1 vs. 3 |
|---|---|---|---|---|---|---|
| Day 4 to 7 | | | | | | |
| % of ADFI | 59.48 ± 4.0 | 55.01 ± 8.1 | 55.03 ± 6.7 | .61 | .55 | .61 |
| % of absorbed | 65.52 ± 7.2 | 64.21 ± 1.6 | 63.20 ± 1.3 | .94 | .88 | .94 |
| Day 8 to 11 | | | | | | |
| % of ADFI | 38.59 ± 3.9 | 57.01 ± 6.7 | 51.73 ± 5.9 | .02 | .05 | .02 |
| % of absorbed | 34.44 ± 6.9 | 65.49 ± 1.3 | 58.72 ± 1.1 | .04 | .07 | .04 |
| Day 12 to 15 | | | | | | |
| % of ADFI | 57.82 ± 3.9 | 57.25 ± 6.7 | 59.43 ± 5.9 | .94 | .81 | .94 |
| % of absorbed | 63.92 ± 6.9 | 65.59 ± 1.3 | 66.67 ± 1.1 | .91 | .83 | .91 |
| Day 16 to 19 | | | | | | |
| % of ADFI | 55.06 ± 3.9 | 46.59 ± 6.7 | 49.18 ± 5.9 | .26 | .38 | .26 |
| % of absorbed | 60.97 ± 6.9 | 56.22 ± 1.3 | 57.88 ± 1.1 | .75 | .81 | .75 |
| Day 22 to 25 | | | | | | |
| % of ADFI | 50.98 ± 3.9 | 41.09 ± 6.7 | 44.93 ± 5.9 | .19 | .37 | .19 |
| % of absorbed | 56.36 ± 6.9 | 48.77 ± 1.3 | 52.30 ± 1.1 | .61 | .76 | .61 |
| Day 8 to 25 | | | | | | |
| % of ADFI | 52.19 ± 2.5 | 51.23 ± 3.7 | 51.95 ± 3.3 | .80 | .95 | .86 |
| % of absorbed | 56.09 ± 3.3 | 59.69 ± 6.1 | 59.49 ± 5.3 | .60 | .58 | .98 |

[a]Thirty five pigs were used in a randomized incomplete block design with individual pig as the experimental unit. *S. typhimurium* challenge occurred on d 8. Effects were analyzed using a mixed model with repeated measures.
[b]A status × time interaction (P<.05) was observed for N retention efficiency as a percent of ADFI.

**Table 6. Effects of *S. typhimurium* Challenge and Feeding Regimen on Blood Growth and Immune Status Indicators in 65 to 125 lb Pigs[a]**

| | *S. typhimurium* | Nonchallenged | | Probability (P <) | | |
|---|---|---|---|---|---|---|
| | Ad-libitum | Ad-libitum | Pair-fed | | | |
| Item[b] | (Trt 1) | (Trt 2) | (Trt 3) | 1 vs. 2 | 1 vs. 3 | 2 vs. 3 |
| Day 5 | | | | | | |
| Haptoglobin, mg Hgb/dL | 39 ± 6.3 | 48 ± 8.6 | 42 ± 7.9 | .22 | .67 | .46 |
| IGF-I, ng/mL | 342 ± 34.7 | 289 ± 49.9 | 305 ± 47.2 | .28 | .42 | .78 |
| Seg. Neutrophil/mL | 5987 ± 1035 | 6680 ± 1530 | 7803 ± 1445 | .65 | .21 | .53 |
| Monocyte/mL | 989 ± 127 | 513 ± 201 | 1092 ± 188 | .03 | .61 | .02 |
| Day 9 | | | | | | |
| Haptoglobin, mg Hgb/dL | 57 ± 6.3 | 39 ± 8.6 | 51 ± 7.9 | .02 | .39 | .18 |
| IGF-I, ng/mL | 293 ± 35.0 | 331 ± 49.9 | 323 ± 45.2 | .44 | .50 | .88 |
| Seg. Neutrophil/mL | 7603 ± 1046 | 5796 ± 1530 | 6538 ± 1377 | .24 | .44 | .67 |
| Monocyte/mL | 988 ± 129 | 864 ± 201 | 892 ± 178 | .56 | .62 | .91 |
| Day 13 | | | | | | |
| Haptoglobin, mg Hgb/dL | 69 ± 6.3 | 31 ± 8.6 | 47 ± 7.9 | .001 | .002 | .07 |
| IGF-I, ng/mL | 306 ± 35.1 | 333 ± 49.9 | 334 ± 45.2 | .58 | .53 | .99 |
| Seg. Neutrophil/mL | 5729 ± 1065 | 6117 ± 1637 | 6381 ± 1445 | .82 | .66 | .89 |
| Monocyte/mL | 1049 ± 131 | 847 ± 216 | 820 ± 188 | .38 | .26 | .92 |
| Day 17 | | | | | | |
| Haptoglobin, mg Hgb/dL | 48 ± 6.3 | 38 ± 8.6 | 34 ± 7.9 | .22 | .06 | .66 |
| IGF-I, ng/mL | 433 ± 34.7 | 340 ± 49.9 | 326 ± 47.2 | .06 | .02 | .81 |
| Seg. Neutrophil/mL | 12745 ± 1035 | 6264 ± 1530 | 6801 ± 1377 | .001 | .001 | .76 |
| Monocyte/mL | 973 ± 127 | 578 ± 201 | 712 ± 178 | .06 | .17 | .58 |
| Day 23 | | | | | | |
| Haptoglobin, mg Hgb/dL | 39 ± 6.8 | 28 ± 8.6 | 39 ± 7.9 | .20 | .99 | .26 |
| IGF-I, ng/mL | 401 ± 35.1 | 293 ± 49.9 | 357 ± 45.2 | .03 | .32 | .25 |
| Seg. neutrophil/mL | 7705 ± 1073 | 5530 ± 1530 | 5942 ± 1377 | .16 | .21 | .81 |
| Monocyte/mL | 863 ± 133 | 664 ± 201 | 600 ± 178 | .35 | .18 | .79 |

[a]Thirty five pigs were used in a randomized incomplete block design with individual pig as the experimental unit. *S. typhimurium* challenge occurred on d 8. Results are expressed for serum haptoglobin, plasma IGF-I, and whole blood segmented neutrophils and monocytes. Effects were analyzed using a mixed model with repeated measures.

[b]A status × time interaction (P<.05) was observed for haptoglobin and segmented neutrophils. A linear time effect (P<.05) was observed for IGF-I. A tendency for a linear time effect (P<.09) was observed for monocyte levels.

| | *S. typh.* | Pair-fed | Ad lib control |
|---|---|---|---|
| Fig. 2. d 5 | 38.5 | 41.5 | 48.2 |
| d 9 | 57.4 | 51.2 | 39.2 |
| d 13 | 69.2 | 47 | 30.6 |
| d 17 | 47.8 | 34 | 38 |
| d 23 | 38.6 | 38.5 | 28.3 |

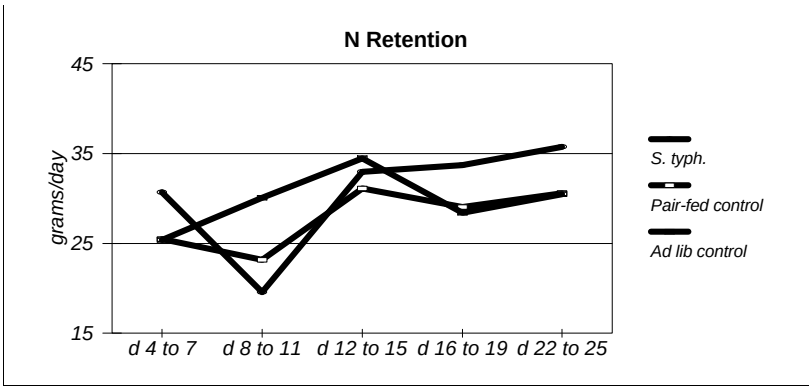



Figure 1. Effects of S. Typhimurium Challenge and Feeding Regimen on Nitrogen Retention in 65 to 125 lb Pigs.

| | | | |
|---|---|---|---|
| Fig. 3. d 5 | 342 | 305 | 289 |
| d 9 | 293 | 323 | 331 |
| d 13 | 306 | 334 | 333 |
| d 17 | 433 | 326 | 340 |
| d 23 | 401 | 357 | 293 |

| | | | |
|---|---|---|---|
| Fig. 1. d 4 to 7 | 30.69 | 25.5 | 25.38 |
| d 8 to 11 | 19.59 | 23.17 | 30.09 |
| d 12 to 15 | 32.97 | 31.11 | 34.48 |
| d 16 to 19 | 33.73 | 29.07 | 28.43 |
| d 22 to 25 | 35.75 | 30.6 | 30.49 |

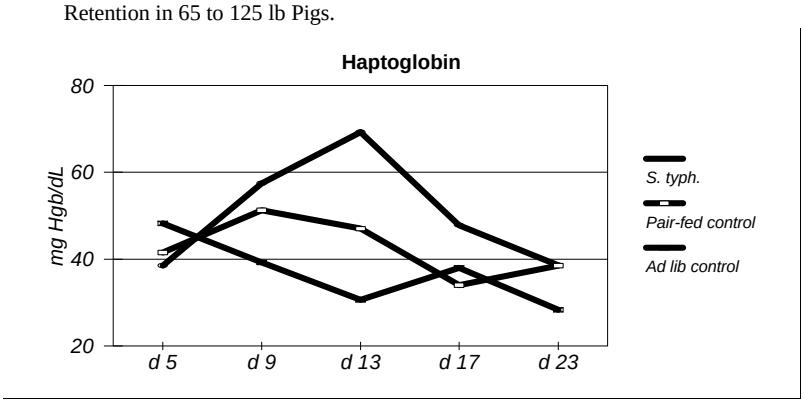



Figure 2. Effects of S. Typhimurium Challenge and Feeding Regimen on Serum Haptoglobin Levels in 65 to 125 lb Pigs.

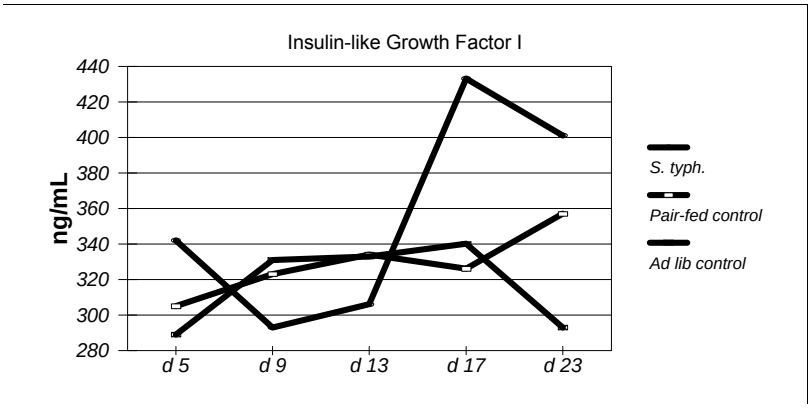



Figure 3. Effects of S. Typhimurium Challenge and Feeding Regimen on Plasma IGF-I Levels in 65 to 125 lb Pigs.

*Swine Day 1998*

# DETERMINING FEED BUDGETS FOR FARM-SPECIFIC NUTRITIONAL PROGRAMS

***M. D. Tokach [1], S. S. Dritz [2], R. D. Goodband, and J. L. Nelssen***

## Summary

Use of feed budgets simplifies feed delivery and improves the accuracy of delivering diets to the correct pig weight ranges during the nursery and finishing periods. Little information has been available for determining farm-specific feed budgets in the past. In this paper, we will outline simple methods to customize a feed budget for individual farms using feed efficiency from past closeout records.

## Procedures

Several steps must be considered when developing farm-specific feed budgets. The first step is determining whether the budget must be changed with season. If feed efficiency is seasonal, the amount of feed to be fed during each particular phase of the growing period must be changed. The data in Figure 1 indicate the seasonality of average daily gain and average daily feed intake. These data were derived from a study at the University of Minnesota. The data include 528 batches of pigs with approximately 10 closeouts for each week of the year. These data were converted into a ratio relative to the mean to determine an adjustment factor for gain, feed intake and feed efficiency (Figure 2). Feed intake varies 5% above and below the mean. The variation for gain is also about 5%; however, the seasonal patterns for gain and intake are quite similar. Thus, the seasonal adjustment for feed efficiency is relatively small (1 to 2%) and of little importance in assigning feed budgets.

Because the seasonal impact on feed efficiency is small, the same feed budget can be used throughout the year. To establish the feed budget, we must know the amount of feed used to reach each weight break and determine the quantity to feed during each stage by difference in the end points. Using the results of several trials, we have developed a standard feed usage curve to use in the finishing period. This curve can be expressed with the following equation:

$$\text{Total feed used} = 0.00463 \times \text{weight}^2 + 1.68 \times \text{weight} - 22.05.$$

This curve has a base feed efficiency of 3.069 from 50 to 250 lb. This curve can be scaled up or down to the level of feed efficiency measured in a particular production system. In order to adjust the curve to a particular system, the feed efficiency from 50 to 250 lb must be determined. Because past closeouts rarely begin and end at exactly 50 and 250 lb, respectively, the following equation can be used to determine the adjusted feed efficiency:

$$\text{Adjusted feed efficiency} = \text{Actual F/G} - ((\text{Initial wt} - 50) \times 0.006) + ((250 - \text{final wt}) \times 0.006).$$

The total feed used by each weight is divided by 3.09 and multiplied by the adjusted feed efficiency to determine the amount of feed used for the adjusted feed efficiency. To simplify these calculations, we provide Table 1 with total feed used calculated for several adjusted feed efficiencies.

[1]Northeast Area Extension Office, Manhattan, KS.
[2]Food Animal Health and Management Center.

These numbers can be used to determine individual feed budgets for any weight breaks. An example is provided in Table 2. We also have developed a spreadsheet to easily calculate the budget and help with feed deliveries. The spreadsheet is in Microsoft Excel format and can be obtained from Mike Tokach at 785-532-2032.

Two problems can occur with this approach. First, we assume that all farms have similar shapes for feed efficiency curves. Although this assumption is too simplistic, the error that it causes does not prevent us from developing relatively accurate feed budgets. The second problem is that this approach does not consider wide variations in energy content or change in diet form from one phase to the next; for example, if pelleted diets or high energy diets are used in one phase and not in another. The relative feed efficiency during the phase with the pelleted or high energy diets would be lower than calculated. Conversely, the feed efficiency will be higher than calculated in the other stages. If the various growing-finishing stages do not have similar energy levels, the feed budget may need to be adjusted accordingly.

How to improve on the feed budget? We recommend using these methods to determine an initial feed budget. Then you can test weigh pigs when diets are changed to determine if they have reached or exceeded the target finishing weight for each stage and adjust the budget accordingly.

**Table 1. Cumulative Feed Usage (lb/pig) during the Finishing Period**

| | Adjusted Feed Efficiency[a] | | | | | |
|---|---|---|---|---|---|---|
| Pig Weight, lb | 2.4 | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 |
| 50 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 | 17 | 19 | 20 | 21 | 23 | 24 |
| 70 | 35 | 38 | 41 | 44 | 47 | 50 |
| 80 | 54 | 58 | 62 | 67 | 71 | 76 |
| 90 | 73 | 79 | 85 | 91 | 97 | 103 |
| 100 | 93 | 101 | 108 | 116 | 124 | 132 |
| 110 | 114 | 123 | 133 | 142 | 151 | 161 |
| 120 | 135 | 146 | 158 | 169 | 180 | 191 |
| 130 | 157 | 170 | 183 | 197 | 210 | 223 |
| 140 | 180 | 195 | 210 | 225 | 240 | 255 |
| 150 | 204 | 221 | 238 | 255 | 272 | 289 |
| 160 | 228 | 247 | 266 | 285 | 304 | 323 |
| 170 | 253 | 274 | 295 | 317 | 338 | 359 |
| 180 | 279 | 302 | 326 | 349 | 372 | 395 |
| 190 | 306 | 331 | 357 | 382 | 407 | 433 |
| 200 | 333 | 361 | 388 | 416 | 444 | 472 |
| 210 | 361 | 391 | 421 | 451 | 481 | 511 |
| 220 | 390 | 422 | 454 | 487 | 519 | 552 |
| 230 | 419 | 454 | 489 | 524 | 559 | 594 |
| 240 | 449 | 487 | 524 | 561 | 599 | 636 |
| 250 | 480 | 520 | 560 | 600 | 640 | 680 |
| 260 | 512 | 554 | 597 | 640 | 682 | 725 |
| 270 | 544 | 589 | 635 | 680 | 725 | 771 |
| 280 | 577 | 625 | 673 | 721 | 769 | 817 |
| 290 | 611 | 662 | 713 | 763 | 814 | 865 |
| 300 | 645 | 699 | 753 | 807 | 860 | 914 |

[a]Adjusted feed efficiency is adjusted to the period from 50 to 250 lb using the following equation: Adjusted F/G = Actual F/G -((Initial wt-50)×0.006)+((250-final wt)×0.006).

**Table 2. Example Feed Budgets (lb/pig) Based on Adjusted Feed Efficiency.**

| | Adjusted feed efficiency[a] | | | | | |
|---|---|---|---|---|---|---|
| Pig weight, lb | 2.4 | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 |
| 50 to 80 | 54 | 58 | 62 | 67 | 71 | 76 |
| 80 to 120 | 81 | 88 | 96 | 102 | 109 | 115 |
| 120 to 160 | 93 | 101 | 108 | 116 | 124 | 132 |
| 160 to 200 | 105 | 114 | 122 | 131 | 140 | 149 |
| 200 to 250 | 147 | 159 | 172 | 184 | 196 | 208 |

[a]Adjusted feed efficiency is adjusted to the period from 50 to 250 lb using the following equation: Adjusted F/G = Actual F/G -((Initial wt-50)*0.006)+((250-final wt)*0.006).

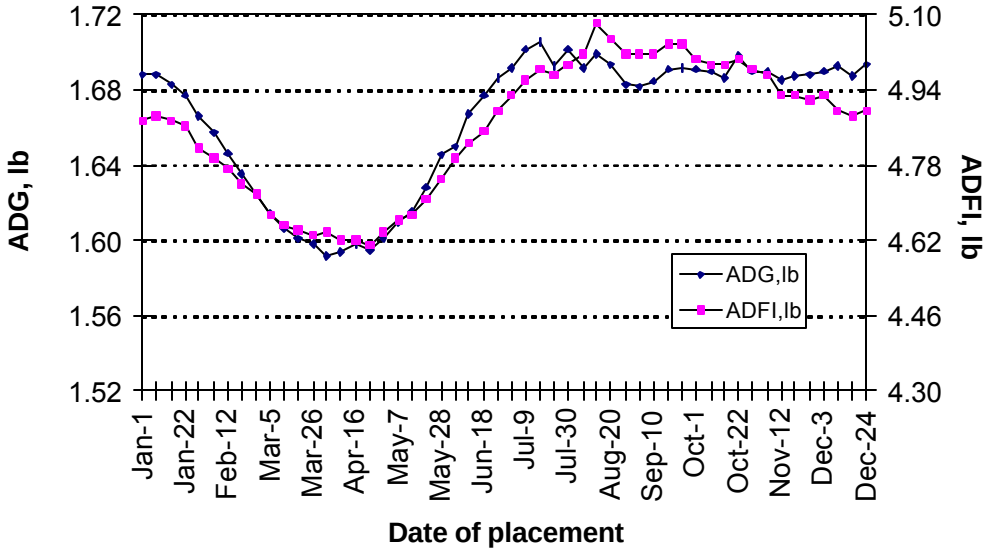



**Figure 1. Influence of Season on Average Daily Gain and Feed Intake.**

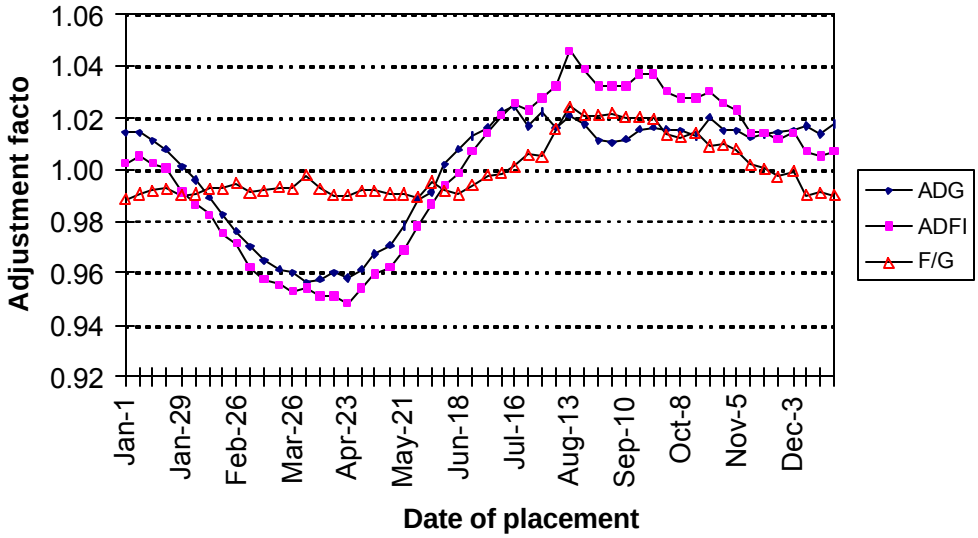



**Figure 2. Adjustment Factors for the Influence of Season on Growing-Finishing Performance.**

# EFFECTS OF INCREASING L-LYSINE HCl ON FINISHING PIG GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS

*M. De La Llata, M. D. Tokach [1], R. D. Goodband, J. L. Nelssen, S. S. Dritz [2], and J. A. Loughmiller*

## Summary

We conducted two studies to determine the effects of increasing L-lysine HCl in finishing pig diets. Experiment 1 used sorghum-soybean meal-based diets, and Exp. 2 used corn-soybean meal-based diets. Treatments included a control diet (no L-lysine HCl) or .15, .225, and .30% L-lysine HCl replacing the lysine provided by soybean meal. In Exp. 1, increasing L-lysine HCl from 0 to .15% had no effect on ADG, F/G, and percentage lean; however, pigs fed .225 and .30% L-lysine HCl had poorer ADG, F/G, and percentage lean. In Exp. 2, ADG and F/G were poorer for pigs fed .225 or .30% L-lysine HCl compared with those fed the control diet or .15% L-lysine. Carcass charactistics were not affected by dietary treatment but tended to become poorer in pigs fed .225 or .30% L-lysine HCl. Unless diets are fortified with other amino acids, no more than .15% (3 lb/ton) L-lysine HCl should be added to sorghum- and corn-soybean meal finishing diets.

(Key Words: Lysine, Sorghum, Corn, Finishing Pigs.)

## Introduction

Over the past few years, an effort has been made to reduce excess crude protein concentrations in swine diets by replacing soybean meal with synthetic lysine (L-lysine HCl). This has the advantage of lowering N excretion in swine waste, and in most cases, diet cost also can be reduced. Although adding increasing amounts of L-lysine generally will decrease diet costs, a potential exists that deficiencies of other amino acids will decrease pig performance. However, if diets are formulated in excess of the pig's lysine requirement, the amount of L-lysine HCL that can be added at the expense of soybean meal can be grossly overestimated. Therefore, the objective of this experiment was to determine how much L-lysine HCl can be added to sorghum- or corn-soybean meal finishing diets without adversely affecting pig growth performance and carcass traits.

## Procedures

Both experiments used similar procedures and methods with the exception that Exp. 1 used sorghum-soybean meal-based diets (Table 1) and Exp. 2 used corn-soybean meal-based diets (Table 2).

One hundred and sixty PIC (L326 × C22) finishing pigs were used in each experiment with initial average weights of 124 and 138 lb (Exps. 1 and 2, respectively). Pigs were allotted randomly on the basis of initial weight to one of the four dietary treatments in a randomized complete block design. There were four pens per treatment (two of gilts and two of barrows). Gilts and barrows were penned separately, with 10 pigs per pen. Diets were fed in growing (120 to 180 lb) and finishing (180 to 240 lb) phases. Growing diets were formulated to contain .70% lysine, and finishing diets to contain .55% lysine. The lysine levels used were estimated to be at or slightly below the requirement estimates

[1]Northeast Area Extension Office, Manhattan, KS.
[2]Food Animal Health and Management Center.

for these weight ranges. Overestimating the lysine requirement for these pigs could have confounded our data by providing high levels of other amino acids, thus overestimating the amount of L-lysine HCl that can be added to a diet. Treatments included a control diet (no added L-lysine HCL) or increasing L-lysine HCl (.15, .225 and .30% of the diet) replacing the lysine provided by soybean meal.

Pigs were housed at the Kansas State University Swine Teaching and Research Center in pens with 50% slatted and 50% solid flooring. Pigs were allowed to ad libitum access to food and water through a dry feeder and one nipple waterer per pen.

All pigs and feeders were weighed every 14 d to calculate ADG, ADFI, and F/G. When the mean weight of pigs reached 180 lb, all pigs were switched from growing to finishing diets. At the termination of the study, pigs were sent to a USDA-inspected packing plant for carcass data collection.

## Results and Discussion

**Experiment 1.** During the growing phase (120 to 180 lb), increasing L-lysine HCl from .15% to .225 and .30% decreased (P<.05) ADG, and F/G tended to become poorer with increasing L-lysine HCl (Table 3). During the finishing phase (180 to 250 lb) and for the overall experimental period, ADG decreased and F/G became poorer (P<.05) for pigs fed .225 and .30% L-lysine HCl compared with those fed control or .15% L-lysine. Backfat depth was increased in pigs fed .15 or .225% L-lysine HCl compared with those fed the control diet, and pigs fed .30% L-lysine HCl had the greatest backfat depth (P>.05). Loin eye depth was not affected by increasing L-lysine HCl. Percentage lean was not different between pigs fed the control diet and .15% L-lysine HCl but was decreased (P<.05) in pigs fed either .225 or .30% compared with controls. Fat-free lean index decreased (P<.05) with increasing L-lysine HCl additions.

**Experiment 2**. During the growing phase, ADG was decreased and F/G was poorer for pigs fed .30% L-lysine HCl compared to those fed other dietary treatments. However, a numerical trend occurred for the same decrease in growth performance observed for pigs fed .225% L-lysine as in Exp. 1. During the finishing phase and for the overall experimental period, ADG and F/G were not affected by addition of .15% L-lysine compared to pigs fed the control diet; however, increasing L-lysine HCl (.225 or .30%) decreased ADG and resulted in poorer F/G (P<.05). Unlike Exp. 1, we did not observe any difference in carcass characteristics with increasing L-lysine HCl. However, note that carcass leanness tended to decrease numerically, especially in those pigs fed .30% L-lysine HCl.

These results suggest that if soybean meal is replaced with greater than .15% L-lysine HCl in sorghum- or corn-soybean meal-based diets, other amino acids will limit growth performance. Thus, no more than .15% (3 lb/ton) of L-lysine HCl should be added to sorghum-corn-soybean meal finishing diets.

**Table 1. Diet Compositions (Exp. 1)**

| | Growing | | | | Finishing | | | |
|---|---|---|---|---|---|---|---|---|
| | L-lysine HCl, lb/ton | | | | L-lysine HCl, lb/ton | | | |
| Ingredient, % | 0 | 3 | 4.5 | 6 | 0 | 3 | 4.5 | 6 |
| Sorghum | 80.57 | 84.52 | 86.65 | 88.74 | 85.79 | 89.90 | 91.80 | 93.90 |
| Soybean meal, 46.5% | 17.10 | 12.90 | 10.70 | 8.50 | 11.80 | 7.50 | 5.50 | 3.30 |
| Monocalcium phosphate | .78 | .85 | .90 | .93 | .88 | .95 | .98 | 1.00 |
| Limestone | .90 | .88 | .88 | .88 | .88 | .85 | .85 | .85 |
| Salt | .35 | .35 | .35 | .35 | .35 | .35 | .35 | .35 |
| Vitamin premix | .15 | .15 | .15 | .15 | .15 | .15 | .15 | .15 |
| Trace mineral premix | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 |
| Tylosin (40 grms/ton) | .05 | .05 | .05 | .05 | .05 | .05 | .05 | .05 |
| Lysine HCl | -- | .15 | .22 | .30 | -- | .15 | .22 | .30 |
| Calculated analysis | | | | | | | | |
| Lysine, % | .70 | .70 | .70 | .70 | .55 | .55 | .55 | .55 |
| ME, kcal/lb | 1,461 | 1,456 | 1,453 | 1,451 | 1,458 | 1,453 | 1,450 | 1,447 |
| Protein, % | 15.10 | 13.50 | 12.70 | 11.90 | 13.10 | 11.50 | 10.70 | 9.90 |
| Calcium, % | .55 | .55 | .55 | .55 | .55 | .55 | .55 | .55 |
| Phosphorus, % | .50 | .50 | .50 | .50 | .50 | .50 | .50 | .50 |

**Table 2. Diet Compositions (Exp. 2)**

| | Growing | | | | Finishing | | | |
|---|---|---|---|---|---|---|---|---|
| | L-lysine HCl, lb/ton | | | | L-lysine HCl, lb/ton | | | |
| Ingredient, % | 0 | 3 | 4.5 | 6 | 0 | 3 | 4.5 | 6 |
| Corn | 81.17 | 85.17 | 87.25 | 89.3 | 86.50 | 90.50 | 92.58 | 94.60 |
| Soybean meal, 46.5% | 16.50 | 12.30 | 10.10 | 8.00 | 11.10 | 6.90 | 4.70 | 2.60 |
| Monocalcium phosphate | .79 | .85 | .90 | .93 | .88 | .95 | 1.00 | 1.00 |
| Limestone | .89 | .88 | .88 | .88 | .88 | .88 | .85 | .85 |
| Salt | .35 | .35 | .35 | .35 | .35 | .35 | .35 | .35 |
| Vitamin premix | .15 | .15 | .15 | .15 | .15 | .15 | .15 | .15 |
| Trace mineral premix | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 |
| Tylosin (40 grms/ton) | .05 | .05 | .05 | .05 | .05 | .05 | .05 | .05 |
| Lysine HCl | -- | .15 | .22 | .30 | -- | .15 | .22 | .30 |
| Calculated analysis | | | | | | | | |
| Lysine, % | 0.70 | 0.70 | 0.70 | 0.70 | 0.55 | 0.55 | 0.55 | 0.55 |
| ME, kcal/lb | 1,513 | 1,510 | 1,509 | 1,507 | 1,512 | 1,509 | 1,508 | 1,507 |
| Protein, % | 14.60 | 12.90 | 12.10 | 11.30 | 12.50 | 10.90 | 10.10 | 9.20 |
| Calcium, % | .55 | .55 | .55 | .55 | .55 | .55 | .55 | .55 |
| Phosphorus, % | .50 | .50 | .50 | .50 | .50 | .50 | .50 | .50 |

**Table 3. Influence of Increasing Synthetic Lysine Additions on Growth Performance and Carcass Characteristics of Growing Pigs (Exp. 1)[a]**

| | HCl-Lysine, lb | | | | |
|---|---|---|---|---|---|
| Item | 0 | 3 | 4.5 | 6 | CV, % |
| Growing (d 0 to 27) | | | | | |
| ADG, lb | 2.04[bc] | 2.10[b] | 1.89[c] | 1.88[c] | 6.2 |
| ADFI, lb | 6.14[b] | 6.63[c] | 6.32[bd] | 6.48[cd] | 2.4 |
| F/G | 3.03[b] | 3.16[bd] | 3.35[bd] | 3.48[cd] | 4.8 |
| Finishing (d 27 to 68) | | | | | |
| ADG, lb | 1.99[b] | 1.95[b] | 1.69[c] | 1.63[c] | 6.2 |
| ADFI, lb | 7.55[b] | 7.83[b] | 7.78[b] | 7.75[b] | 3.8 |
| F/G | 3.80[b] | 4.01[b] | 4.64[c] | 4.86[c] | 9.4 |
| Overall (d 0 to 68) | | | | | |
| ADG, lb | 2.01[b] | 2.01[b] | 1.77[c] | 1.73[c] | 4.4 |
| ADFI, lb | 7.01[b] | 7.34[cd] | 7.18[bd] | 7.24[bd] | 2.8 |
| F/G | 3.49[b] | 3.65[b] | 4.07[c] | 4.21[c] | 5.1 |
| Packing plant data | | | | | |
| Live weight, lb[e] | 261.3[b] | 261.2[b] | 246.5[c] | 242.1[c] | 2.4 |
| Backfat, in | 0.566[b] | 0.633[c] | 0.681[c] | 0.737[d] | 4.6 |
| Carcass yield, % | 64.04[b] | 65.02[cd] | 64.06[bd] | 63.99[bd] | 0.8 |
| L.E. depth, in | 2.08[b] | 2.11[b] | 2.04[b] | 2.05[b] | 5.5 |
| Lean percentate | 56.60[b] | 55.70[bd] | 54.59[cd] | 53.51[c] | 1.2 |
| Fat-free lean index | 51.10[b] | 50.34[c] | 49.66[c] | 48.83[d] | 0.8 |

[a]One hundred and sixty PIC (L326 × C15) finishing pigs. Initial weight 125 lb.
[b,c,d]Means in a row with similar letter are not different (P<.05).
[e]Live weight was used as a covariate to analyze the packing plant data.

**Table 4. Influence of Increasing Synthetic Lysine Additions on Growth Performance and Characteristics of Growing Pigs (Exp. 2)[a]**

| | HCl-Lysine, lb | | | | |
|---|---|---|---|---|---|
| Item | 0 | 3 | 4.5 | 6 | CV, % |
| Growing (d 0 to 24) | | | | | |
| ADG, lb | 2.13[b] | 2.15[b] | 2.04[b] | 1.81[c] | 5.69 |
| ADFI, lb | 6.41[b] | 6.54[b] | 6.40[bc] | 6.21[c] | 2.98 |
| F/G | 3.02[b] | 3.04[b] | 3.15[b] | 3.43[c] | 3.55 |
| Finishing (d 24 to 54) | | | | | |
| ADG, lb | 2.05[b] | 1.92[bc] | 1.76[c] | 1.42[d] | 8.09 |
| ADFI, lb | 7.35[b] | 7.00[b] | 7.08[b] | 6.13[c] | 3.29 |
| F/G | 3.60[b] | 3.72[b] | 4.03[c] | 4.33[c] | 5.13 |
| Overall (d 0 to 54) | | | | | |
| ADG, lb | 2.08[b] | 2.01[bc] | 1.88[c] | 1.59[d] | 4.38 |
| ADFI, lb | 6.92[b] | 6.81[b] | 6.77[b] | 6.16[c] | 2.83 |
| F/G | 3.32[b] | 3.39[b] | 3.61[c] | 3.87[d] | 5.11 |
| Packing plant data | | | | | |
| Live weight, lb[e] | 251.9[b] | 246.8[bc] | 239.6[c] | 224.1[d] | 2.23 |
| Backfat, in | 0.612 | 0.589 | 0.591 | 0.677 | 12.38 |
| Carcass yield, % | 64.17 | 64.26 | 65.23 | 64.33 | 1.23 |
| L.E. depth, in | 2.38 | 2.32 | 2.30 | 2.29 | 4.89 |
| Lean percentage | 56.63 | 56.81 | 56.69 | 55.37 | 1.98 |
| Fat-free lean index | 50.06 | 50.25 | 50.52 | 49.79 | 1.81 |

[a]One hundred and sixty PIC (L326 × C15) finishing pigs. Initial weight 138.1 lb.
[b,c,d]Means with different superscripts differ (P<.05).
[e]Live weight was used as a covariate to analyze the packing plant data.

# EFFECTS OF WHOLE GRAIN AND DISTILLERS DRIED GRAINS WITH SOLUBLES FROM NORMAL AND HETEROWAXY ENDOSPERM SORGHUMS ON GROWTH PERFORMANCE, NUTRIENT DIGESTIBILITY, AND CARCASS CHARACTERISTICS OF FINISHING PIGS [1]

***B. W. Senne, J. D. Hancock, R. H.Hines, D. W. Dean, I. Mavromichalis, and J. R. Froetschner***

## Summary

No differences occurred in ADG, ADFI, F/G, digestibilities of DM and GE, dressing percentage, 10th rib fat depth, or fat free lean index in pigs fed normal vs heterowaxy sorghums. As anticipated, with the greater fiber and lower energy in distillers dried grains with solubles (DDGS) than the parent cereal grains, ADG and digestibilities of DM and GE were lower and F/G was worse for pigs fed DDGS. However, the energy value of the DDGS was affected less adversely when heterowaxy sorghum was used for fermentation to ethanol.

(Key Words: Sorghum, Distillers Grains, Waxy, Endosperm, Finishing Pigs.)

## Introduction

Several factors can affect the feeding value of sorghum grain. One of those factors, endosperm type, has been examined by many researchers in an attempt to improve the quality and digestibility of sorghum compared to corn. Sorghum endosperm can be classified as normal, intermediate (heterowaxy), or waxy. Waxy sorghums have poor seed germination and vigor, but these agronomic maladies are not shared by normal or heterowaxy sorghums.

Distillers dried grains with solubles (DDGS) are coproducts of the ethanol industry. Previous research from our laboratory has shown that finishing pigs can be fed up to 60% DDGS with no adverse effects on performance, if fat is added to keep ME of the diets constant. However, few data exist to evaluate the source of the DDGS (i.e., from normal, heterowaxy, or waxy sorghum). Therefore, we designed two experiments to compare the effects of normal and heterowaxy endosperm sorghums and their respective DDGS on finishing pigs.

## Procedures

One-hundred ninety-two finishing pigs (PIC line 326 boars × C-15 and C-22 sows) were blocked by weight (average initial wt of 143 lb) and allotted to treatments on the basis of sex and ancestry. They were housed in a modified-open-front building with 50% solid concrete and 50% concrete slat flooring. Sixteen pens (eight pens of barrows and eight pens of gilts) were used with four pens per treatment. Each 6-ft × 16-ft pen had a two-hole feeder and a nipple waterer to allow ad libitum access to feed and water.

The heterowaxy sorghum was obtained from NC+ Hybrids, and the normal endosperm sorghum (mill run) was supplied by High Plains Ethanol of Colwich, KS. Both sorghums were grown in south-central Kansas and fermented at High Plains Ethanol. The diets (Table 1) were formulated to .9% lysine, .6% Ca, and .5% P. The diets with whole grain had 3.2 Mcal ME/lb and the diets

[1]The authors express appreciation to Mike Lenz of NC+ Hybrids for providing the seed used in this experiment and to Greg Hauer of High Plains Ethanol for use of their facilities. Also, we thank the Kansas State Board of Agriculture and the Kansas Sorghum Commission for funding this project.

with DDGS had 3.0 Mcal ME/lb. All diets were fed in mash form.

Pigs and feeders were weighed at initiation and conclusion of the experiment to allow calculation of ADG, ADFI, and F/G. Six weeks after initiation of the experiment, $Cr_2O_3$ was added (.25%) to all diets as an indigestible marker. Feed and fecal samples were collected twice on d 52 and pooled within pen. Concentrations of DM, N, GE and Cr in the feces and feed were determined to allow calculation of apparent digestibilities of DM, N, and GE. On d 59, nine pigs from each pen (144 total) were slaughtered to determine 10th rib fat depth and hot carcass weight. Dressing percentage was calculated, with hot carcass weight as a percentage of preshipping live weight. Fat-free lean index was calculated using NPPC equations.

All data were analyzed as a randomized complete block design with initial weight as the blocking criterion and pen as the experimental unit. Orthogonal contrasts were used to separate treatment means. Slaughter weight was used as a covariate for analyses of the carcass data.

In a second experiment, 48 barrows and gilts (avg initial BW of 257 lb and avg final BW of 263 lb) were used in a 6-d experiment to determine the digestibilities of DM, N, and GE for the two sorghum grains and the two distillers grains. Sorghum diets (Table 2) had 97% sorghum and DDGS diets had 98% DDGS. The diets were formulated to meet NRC recommendations for all nutrients and had .25% $Cr_2O_3$ included as an indigestible marker. All diets were fed in mash form.

Feed and fecal samples were taken on d 5 and 6, pooled within pen, dried, and ground. Concentrations of DM, N, GE, and Cr in the feces and feed were determined to allow calculation of apparent digestibilities.

The data were analyzed as a randomized complete block design with initial weight as the blocking criterion and pen as the experimental unit. Orthogonal contrasts were used to separate the treatment means of endosperm type (normal vs heterowaxy) and grain vs DDGS.

## Results and Discussion

Chemical analyses (Table 3) of the sorghums and DDGS indicated nutrient compositions similar to those observed in previous work here at KSU. Values for CP, ether extract, crude fiber, ash, and amino acids were similar for the two sorghum types. However, the fermentation process (conversion of starch to ethanol) concentrated all nonstarch nutrients.

Endosperm waxiness did not affect ($P>.15$) growth performance or carcass measurements. However, digestibility of N was greater for the heterowaxy sorghum vs normal sorghum ($P<.003$).

Fermentation of the sorghum grain to yield ethanol resulted in DDGS that supported poorer ($P<.03$) rates and efficiencies of gain and lower ($P<.005$) digestibilities of DM and GE. We should note, however, that these responses were anticipated, because no attempt was made to equalize ME in the diets (e.g., by adding fat). Instead, we decided to let any difference in energy value of the DDGS be expressed.

Interactions occurred among endosperm type and grain vs DDGS for ADG ($P<.04$) and digestibility of DM ($P<.03$). These interactions resulted from the greater loss of nutritional value when normal sorghum was fermented to ethanol than when heterowaxy sorghum was used to generate DDGS.

For the digestibility experiment, the diets were virtually all sorghum grain or all DDGS (with minor additions of vitamins and minerals). The heterowaxy sorghum had greater digestibility of N ($P<.10$) and GE ($P<.02$), and greater DE/lb ($P<.003$) than the normal sorghum. Fermentation to yield DDGS decreased digestibility of DM and GE ($P<.001$) and DE/lb ($P<.002$). The only interaction approaching significance ($P<.08$) was for digestibility of DM. Loss of DM digestibility was greater for normal vs heterowaxy sorghum when fermented to yield

DDGS; DE was 1,471 kcal/lb for the normal sorghum and decreased by 145 kcal/lb (to 1,326 kcal/lb) in the normal DDGS. This is in close agreement with the 1998 NRC values for corn DDGS that are reported as 147 kcal/lb less in DE than the parent grain. However, the DE of heterowaxy sorghum (1,552 kcal/lb) decreased by only 83 kcal/lb (to 1,469 kcal/lb) in the DDGS.

In conclusion, heterowaxy sorghum did not improve pig performance or affect carcass measurements compared to normal sorghum. However, our data suggest that all DDGS do not have the same energy value but are affected by endosperm type of the parent grain. Thus, nutritionists should be cautious when using a single NRC value for all DDGS to formulate diets.

**Table 1. Compositions of Diets for the Growth Assay (Exp. 1)**

| Item | Sorghum Grain | DDGS |
|---|---|---|
| Ingredient, % | | |
| Sorghum | 83.33 | - |
| Corn | - | 56.67 |
| Soybean meal (46.5 % CP) | 13.11 | - |
| Distillers dried grains w/solubles | - | 40.00 |
| L-lysine-HCl | .40 | .67 |
| DL-methionine | .17 | - |
| Threonine | .18 | .11 |
| Tryptophan | - | .04 |
| Monocalcium phosphate | .86 | .38 |
| Limestone | 1.01 | 1.21 |
| Vitamin premix | .15 | .15 |
| Trace mineral premix | .10 | .10 |
| Salt | .3 | .3 |
| Chromic oxide[a] | .25 | .25 |
| Antibiotic[b] | .12 | .12 |
| | | |
| Calculated analysis | | |
| CP, % | 14.0 | 15.6 |
| Lysine, % | .90 | .90 |
| Ca, % | .60 | .60 |
| Total P, % | .50 | .50 |
| ME, kcal/lb | 1,449 | 1,364[c] |

[a]Indigestible marker.
[b]Provided 100 g/ton of tylosin.
[c]Diets were formulated with ME concentration of sorghum-based DDGS assumed to be 1,260 kcal/lb (using earlier data from our laboratory).

**Table 2. Compositions of Diets for Digestible Energy Determinations (Exp. 2)**

| Item | Sorghum Grain | DDGS |
|---|---|---|
| Ingredient, % | | |
| Sorghum | 96.86 | - |
| Distillers dried grains w/solubles | - | 98.12 |
| L-lysine-HCl | .354 | - |
| DL-methionine | .045 | - |
| Threonine | .094 | - |
| Monocalcium phosphate | .851 | - |
| Limestone | .968 | 1.08 |
| Vitamin premix | .045 | .045 |
| Trace mineral premix | .085 | .085 |
| Additional vitamin mixture | .025 | - |
| Salt | .3 | .3 |
| Chromic oxide[a] | .25 | .25 |
| Antibiotic[b] | .12 | .12 |
| Calculated analysis | | |
| CP, % | 9.0 | 24.8 |
| Lysine, % | .50 | .57 |
| Ca, % | .55 | .55 |
| Total P, % | .45 | .65 |
| ME, kcal/lb | 1,455 | 1,157[c] |

[a]Indigestible marker.

[b]Provided 100 g/ton tylosin.

[c]Diets were formulated with ME concentration of sorghum-based DDGS assumed to be 1,260 kcal/lb (based on earlier data from our laboratory).

**Table 3. Chemical Compositions of Grain and Distillers Dried Grains with Solubles**

| | Normal Endosperm | | Heterowaxy Endosperm | |
|---|---|---|---|---|
| Item | Grain | DDGS | Grain | DDGS |
| DM, % | 87.38 | 89.97 | 88.60 | 90.92 |
| CP, %[a] | 9.56 | 25.26 | 10.24 | 26.03 |
| Ether extract, %[a] | 3.31 | 9.40 | 3.34 | 9.26 |
| Crude fiber, %[a] | 3.40 | 8.49 | 3.20 | 8.00 |
| Ash,%[a] | 1.36 | 3.94 | 1.44 | 4.77 |
| GE, Mcal/lb[a] | 1.7 | 2.0 | 1.8 | 2.1 |
| Amino acids, %[a] | | | | |
| Arginine | .36 | 1.00 | .39 | 1.09 |
| Histidine | .22 | .64 | .23 | .65 |
| Isoleucine | .38 | 1.31 | .41 | 1.29 |
| Leucine | 1.27 | 3.84 | 1.36 | 3.78 |
| Lysine | .22 | .68 | .24 | .78 |
| Methionine + cystine | .34 | .86 | .40 | .92 |
| Phenylalanine + tyrosine | .80 | 2.63 | .85 | 2.61 |
| Threonine | .31 | 1.03 | .33 | 1.07 |
| Tryptophan | .09 | .21 | .10 | .23 |
| Valine | .48 | 1.57 | .52 | 1.60 |

[a]Dry matter basis.

**Table 4. Effects of Grain and Distillers Dried Grains from Normal and Heterowaxy Endosperm Sorghum on Growth Performance, Nutrient Digestibility, and Carcass Characteristics of Finishing Pigs (Exp. 1)[a]**

| | Normal | | Heterowaxy | | | Contrasts[b] | | |
|---|---|---|---|---|---|---|---|---|
| Item | Sorghum | DDGS | Sorghum | DDGS | CV | 1 | 2 | 3 |
| ADG, lb | 2.02 | 1.79 | 1.91 | 1.89 | 3.2 | -[c] | .03 | .04 |
| ADFI, lb | 7.21 | 7.25 | 6.78 | 7.52 | 5.2 | - | .10 | .12 |
| F/G | 3.56 | 4.05 | 3.54 | 3.97 | 8.3 | - | .02 | - |
| Apparent nutrient digestibility, % | | | | | | | | |
| DM | 85.0 | 79.9 | 83.7 | 82.7 | 5.8 | - | .005 | .03 |
| N | 71.7 | 69.7 | 75.5 | 75.4 | 3.8 | .003 | - | - |
| GE | 83.5 | 77.1 | 82.1 | 75.8 | 6.0 | - | .001 | - |
| Dressing % | 72.2 | 72.6 | 72.5 | 72.5 | 1.4 | - | - | - |
| 10th rib fat thickness, in | .98 | .97 | 1.01 | .95 | 5.5 | - | - | - |
| FLI, %[d] | 48.4 | 48.4 | 48.1 | 48.6 | 1.0 | - | - | - |

[a]A total of 192 pigs (12 pigs per pen and four pens per treatment) with an avg initial BW of 143 lb and an avg final BW of 248 lb.
[b]Contrasts were: 1) normal vs heterowaxy; 2) sorghum vs DDGS; and 3) normal vs heterowaxy × sorghum vs DDGS.
[c]Dashes indicate P>.15.
[d]Fat free lean index (NPPC, 1994).

**Table 5. Digestible Energy of Grain and Distillers Dried Grains from Normal and Heterowaxy Endosperm Sorghums in Finishing Pigs (Exp. 2)[a]**

| | Normal | | Heterowaxy | | | Contrasts[b] | | |
|---|---|---|---|---|---|---|---|---|
| Item | Sorghum | DDGS | Sorghum | DDGS | CV | 1 | 2 | 3 |
| Apparent nutrient digestibility, % | | | | | | | | |
| DM | 84.0 | 64.3 | 83.5 | 71.5 | 7.2 | .11 | .001 | .08 |
| N | 62.9 | 63.3 | 65.3 | 71.2 | 8.8 | .10 | -[c] | - |
| GE | 81.4 | 63.8 | 83.7 | 69.1 | 5.1 | .02 | .001 | - |
| DE of the grain, kcal/lb | 1,471 | 1,326 | 1,552 | 1,469 | 7.1 | .003 | .002 | - |

[a]A total of 48 pigs (three pigs per pen and four pens per treatment) with an avg initial BW of 257 lb and an avg final BW of 263 lb.
[b]Contrasts were: 1) normal vs heterowaxy; 2) sorghum vs DDGS; and 3) normal vs heterowaxy × sorghum vs DDGS.
[c]Dashes indicate P>.15.

# EFFECTS OF MAGNESIUM SILICATE (TALC) ON FEED FLOW CHARACTERISTICS AND GROWTH PERFORMANCE, CARCASS CHARACTERISTICS, AND STOMACH MORPHOLOGY IN FINISHING PIGS [1]

*S. P. Sorrell, J. D. Hancock, S. L. Traylor, S. L. Johnston, I. H. Kim, R. H. Hines, and G. A. Kennedy* [2]

## Summary

Talc did not affect growth performance, carcass characteristics, or stomach ulceration in finishing pigs. Feeder bridging scores and coefficients of static force (the force needed to result in particle movement) were increased with added talc, both of which indicate reduced feed flowability. In a second experiment, reducing particle size from 1,050 microns to 450 microns increased the coefficients of static force, dynamic force, and angle of repose. Adding talc to either particle size diet did not improve feed flow characteristics.

(Key Words: Talc, Ulcers, Bridging, Finishing Pigs.)

## Introduction

Intense competition in the marketplace, resulting from narrow profit margins and consumers demanding leaner pork products, has caused a shift to leaner genetics. Increased building and equipment costs have forced swine producers to maximize use of facilities by increasing stocking densities, while high feed costs have stimulated interest in technologies such as fine grinding of ingredients and pelleting to increase efficiency of feed utilization. Unfortunately, reports indicate that higher lean gain genetics, increased stocking density, fine grinding, and pelleting can precipitate adverse changes in stomach morphology of finishing pigs. Magnesium silicate has been suggested as a feed additive that decreases the incidence of stomach ulceration (report from the France Serebia Center, 1975) and enhances flow characteristics of finely ground feed. Thus, the experiments reported herein were designed to determine the effects of magnesium silicate on growth performance, carcass characteristics, stomach morphology, and feed flowability.

## Procedures

**Experiment 1.** A total of 210 pigs (PIC 326 × C15 with an average initial weight of 120 lb) was used in a 75-d growth assay. The pigs were housed in a modified, open front, finishing facility with half slatted and half solid concrete floors. The pigs were allotted to pens (6 ft × 16 ft) on the basis of weight, sex, and ancestry with 14 pigs per pen (6.4 $ft^2$/pig) and five pens per treatment. Each pen had a nipple waterer and two-hole self-feeder to allow ad libitum consumption of feed and water. The diets were corn (ground to 450 microns in a hammermill)-soybean meal-based with .90% lysine, .65% Ca, and .55% P (Table 1). Treatments were: 1) control; 2) 1.5% talc; and 3) 3% talc.

The pigs were slaughtered when the average weight in the heaviest pen of a weight block reached 250 lb. At slaughter, carcass data were obtained, and the esophageal regions of the stomachs were scored for keratosis and ulceration. Response criteria were ADG, ADFI, feed/gain, backfat thickness, dressing percentage, fat-free lean index,

[1]Appreciation is extended to Greg Hunter and Patrick Delord of Luzena America for funding this project.

[2]Department of Diagnostic Medicine/Pathobiology.

stomach keratinization, and stomach ulceration. Additionally, feeder bridging scores (scale of 0 = none, to 5 = severe) were taken (12 times) the days after all feeders were filled and leveled. Coefficients of static force (the force needed to result in particle movement) and dynamic force (the force needed to stop particle flow after movement has begun) and angle of repose (the maximum angle, in degrees, at which a pile of material retains its shape) also were determined for each batch of feed. Procedures were followed as outlined in Feed Manufacturing Technology IV (American Feed Industry Association, 1994, Arlington, VA). All data were analyzed as a randomized complete block design (initial weight as the blocking term) using the GLM procedure of SAS. Pen was the experimental unit for all analyses, and polynomial regression was used to describe the shape of the response curve.

**Table 1. Diet Composition, %[a]**

| Ingredient | Control |
|---|---|
| Corn | 80.34 |
| Soybean meal | 15.52 |
| Soy oil | 1.00 |
| Vit, Min, Antibiotic[b] | 2.77 |
| Lysine HCl | .30 |
| Threonine | .04 |
| Methionine | .03 |
| Talc[c] | - - |

[a]Formulated to .90% lysine, .65% Ca, and .55% P.
[b]Supplied 100 g/tone tylosin.
[c]Talc treatments resulted from top dressing the diet with none, 1.5%, or 3.0% magnesium silicate.

**Experiment 2.** The diets formulated for experiment 1 (0, 1.5, 3.0% talc) were manufactured with corn ground to three different particle sizes (1,050, 750, and 450 microns) to determine the effects of talc and particle size on feed flow characteristics for finishing pigs. Coefficients of static force, coefficients of dynamic force, and angles of repose were determined as in Exp. 1 on 12 samples of the experimental diets. Concentration of talc and particle size were evaluated as a 3×3 factorial using the GLM Procedure of SAS.

## Results and Discussions

**Experiment 1.** Talc had no effect on ADG, ADFI, or feed/gain (P>.2). Similarly, dressing percentage, last rib backfat thickness, and fat-free lean index were unaffected by talc (P>.2). However, the 1.5 and 3.0% additions of talc resulted in numerical decreases of 1.3 and 2.9% in efficiency of growth. This close correlation (between talc inclusion and efficiency of growth) suggests that the talc was inert and not affecting nutrient digestion and(or) metabolism. Stomach ulceration and keratinization scores (on a scale of 0 = normal to 3 = severe) were not influenced by talc addition (P>.11). Also, even though the pigs were somewhat crowded (6.4 $ft^2$/pig) and fed very finely ground corn (450 microns), only one pig died from an ulcer, and that pig was in a pen given the 3.0% talc diet. This suggests that talc addition had no effect on preventing ulcers.

Diets with talc had greater feeder bridging scores (quadratic effect, P<.03). The force needed to cause the diet to flow (coefficient of static force) also increased with talc addition (P<.005). The force needed to stop the diet from flowing (coefficient of dynamic force) and angles of repose were not affected by talc addition (P>.5).

**Experiment 2.** Decreasing particle size from 1,050 tp 450 microns increased the coefficient of static force (quadratic effect, P<.001), the coefficient of dynamic force (liner effect, P<.001), and the angle of repose (liner effect, P<.001). Decreased feed flowability with decreased particle size is well documented. Furthermore, with very fine particle sizes (e.g., the 450 micron treatment used in our experiment), bridging can become severe. Our question was can talc, as a flow agent, reduce these bridging problems?

The coefficients of static (linear effect, P<.001) and dynamic (quadratic effect, P<.01) forces and the angle of repose (linear effect, P<.001) were increased with talc addition. These bridging increases may have resulted from the fine nature of the talc (a powder) that would tend to increase problems with flowability. Finally, interactions (P<.03) occurred among particle size and talc concentration, with general trends for the negative effects of increasing talc to be greatest in the diets with the largest (1,050 microns) and smallest (450 microns) particle sizes.

In conclusion, our data suggest that addition of talc to diets for finishing pigs did not affect growth performance, carcass characteristics, or stomach morphology. Decreasing particle size from 1,050 to 450 microns did decrease feed flowability of diets for finishing pigs, but talc addition to those diets did not enhance their flow characteristics.

**Table 2. Effects of Talc on Growth Performance, Carcass Characteristics, and Stomach Morphology in Finishing Pigs and Feed Flowability[a]**

| | Concentration of Talc | | | | Contrasts | |
|---|---|---|---|---|---|---|
| Item | Control | 1.5% | 3.0% | SE | Linear | Quadratic |
| ADG, lb | 1.85 | 1.80 | 1.82 | .02 | - -[b] | - - |
| ADFI, lb | 5.64 | 5.57 | 5.71 | .09 | - - | - - |
| F/G | 3.05 | 3.09 | 3.14 | .04 | - - | - - |
| Backfat, in | 1.10 | 1.10 | 1.11 | .02 | - - | - - |
| HCW, lb | 189.9 | 190.6 | 189.8 | .38 | - - | - - |
| Dressing, % | 74.5 | 74.9 | 74.6 | .16 | - - | - - |
| FFLI, % | 47.5 | 47.6 | 47.4 | .20 | - - | - - |
| Feeder bridging scores | 4.05 | 4.31 | 4.32 | .04 | .001 | .03 |
| Coefficient of static force | .81 | .86 | .92 | .12 | .005 | - - |
| Coefficient of dynamic force | .61 | .61 | .61 | .06 | - - | - - |
| Angle of repose | 58.1 | 58.6 | 58.5 | .8 | - - | - - |

[a]A total of 210 pigs (avg initial wt of 120 lb) was used. [b]Dashes indicate P>.15.

**Table 3. Effects of Talc on Stomach Morphology[a]**

| | Concentration of Talc | | | | Contrasts | |
|---|---|---|---|---|---|---|
| Item | Control | 1.5% | 3.0% | SE | Linear | Quadratic |
| Stomach keratinization | | | | | | |
| No. of observations | 67 | 69 | 67 | - - | - - | - - |
| Normal | 29 | 29 | 36 | - - | - - | - - |
| Mild | 17 | 9 | 7 | - - | - - | - - |
| Moderate | 9 | 14 | 12 | - - | - - | - - |
| Severe | 12 | 17 | 12 | - - | - - | - - |
| Mean score[b] | 1.06 | 1.28 | 1.00 | .46 | .95 | .11 |
| Stomach ulceration | | | | | | |
| No. of observations | 67 | 69 | 67 | - - | - - | - - |
| Normal | 24 | 28 | 20 | - - | - - | - - |
| Erosions | 10 | 8 | 16 | - - | - - | - - |
| Ulcers | 23 | 20 | 17 | - - | - - | - - |
| Severe ulcers | 10 | 16 | 14 | - - | - - | - - |
| Mean score[c] | 1.28 | 1.39 | 1.37 | .41 | .46 | .56 |

[a]A total of 210 pigs (avg initial wt of 120 lb) was used and 203 stomachs were collected. [b]The scoring system was: 0 = normal; 1 = mild; 2 = moderate; 3 = severe keratosis. [c]The scoring system was: 0 = normal; 1 = erosion; 2 = ulcer; and 3 = severe ulcer.

**Table 4. Effects of Particle Size and Talc on Flowability of Diets for Finishing Pigs**

| | 1,050 Microns | | | 750 Microns | | | 450 Microns | | | | Contrasts[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | 0[b] | 1.5 | 3.0 | 0 | 1.5 | 3.0 | 0 | 1.5 | 3.0 | SE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Coeff. of static force | .53 | .56 | .60 | .64 | .66 | .67 | .75 | .82 | .84 | .01 | .001 | .001 | .001 | - -[c] | - - | .001 | .03 | - - |
| Coeff. of dynamic force | .48 | .52 | .52 | .58 | .58 | .57 | .58 | .65 | .66 | .01 | .001 | - - | .001 | .01 | .02 | .001 | - - | - - |
| Angle of repose | 48.6 | 50.4 | 51.8 | 52.5 | 54.0 | 54.8 | 58.5 | 57.2 | 58.8 | .4 | .001 | - - | .001 | - - | .001 | - - | .03 | - - |

[a]Contrasts were: 1) particle size linear; 2) particle size quadratic; 3) talc linear; 4) talc quadratic; 5) particle size linear × talc linear; 6) particle size quadratic × talc linear; 7) particle size linear × talc quadratic; 8) particle size quadratic × talc quadratic.
[b]Percentage talc in the diet.
[c]Dashes indicate P>.15.

*Swine Day 1998*

# EFFECTS OF MODIFIED TALL OIL VERSUS CONJUGATED LINOLEIC ACID ON FINISHING PIG GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS [1,2]

***P. R. O'Quinn, J. W. Smith, II, J. L. Nelssen, M. D. Tokach [3], R. D. Goodband, and J. S. Smith***

## Summary

A growth trial was conducted to compare effects of modified tall oil (MTO) and conjugated linoleic acid (CLA) on growth performance, serum chemistry, and carcass composition of finishing barrows. Overall, pigs fed the control diet did not differ from pigs fed MTO or CLA supplemented diets. However, pigs fed MTO had greater ADG and ADFI than pigs fed CLA. No effect of treatment was observed for any of the measured carcass criteria or serum triglyceride levels. The results of this research do not suggest a benefit from feeding MTO or CLA to pigs but do indicate differences in ADG and ADFI that favor those fed MTO.

(Key Words: Modified Tall Oil, Conjugated Linoleic Acid, Growth, Carcass.)

## Introduction

Conjugated linoleic acid (CLA) is a collective term describing several forms of linoleic acid. Linoleic acid (C18:2) has double bonds located at carbons 9 and 12 both in the *cis* configuration. Conjugated linoleic acid has either the *cis* or *trans* configuration or both located on carbons 9 and 11, 10 and 12, or 11 and 13. The *cis* 9, *trans* 11 form of CLA apparently is the biologically active form that can be incorporated into phospholipids in the body. Feeding of CLA to laboratory animals improves rate and efficiency of gain and decreases fat deposition. Tall oil is a nonaqueous layer of rosin acids and fatty acids produced during the kraft (sulfate) paper process. Modified tall oil (MTO) has intrinsic properties that make it suitable for a comparison with CLA. Therefore, the objective of this study was to compare the effects of MTO and CLA on pig growth performance, serum chemistry profiles, and carcass composition.

## Procedures

A total of 36 crossbred barrows (initially 83 lb; PIC L326 × C22) was blocked on the basis of initial weight and ancestry in a randomized complete block design and randomly allotted to the three dietary treatments with six replicate pens per treatment.

Modified tall oil and CLA were substituted on an equal weight basis for soybean oil in the experimental diets. Chemical separation values for the soybean oil, CLA, and MTO samples are presented in Table 1. All diets were fed in meal form. Composition of the basal diets is given in Table 2. Diets were fed in two phases; 80 to 160 and 160 to 230 lb BW. Diets were changed when the average weight of pigs in a block of pens reached 160 lb.

---

[1]Appreciation is extended to Lonza Inc., Fair Lawn, NJ, for partial financial support of this research, and to PharmaNutrients Inc., Lake Bluff, IL, and Hercules Inc., Wilmington, DE, for providing the Tonalin™ CLA 60 and modified tall oil, respectively.

[2]Appreciation also is extended to Dr. Norman Smith of the London Health Sciences Centre, London, Ontario, Canada, for conducting the triglyceride assays.

[3]Northeast Area Extension Office, Manhattan, KS.

Pigs were housed in an environmentally controlled finishing barn with two pigs in each 4 ft × 4 ft pen with a totally slatted floor. Pigs were allowed ad libitum access to feed and water through one single-hole self-feeder and a nipple waterer.

Pigs were weighed every 14 d in order to determine ADG, ADFI, and feed efficiency (F/G). The day before slaughter, plasma blood samples were collected from each pig for analysis of triglyceride (TG) concentrations after a 3 h fast. The samples were pooled for each pen and stored frozen until analyzed.

Pigs were slaughtered when the average weight of pigs in a pen reached 230 lb BW. Standard carcass measurements; visual analyses of the longissimus for coloring, marbling, and firmness; drip loss, and Minolta colorspectrometry (Hunter L*, a*, and b*) were determined for each pig at 24 h postmortem (drip loss = 48 h postmortem).

Data were analyzed as a randomized complete block. Pen was the experimental unit for all calculations. The GLM procedure of SAS was used for the single degree of freedom contrasts among the dietary treatments. Hot carcass weight was used as a covariate in the statistical model for carcass analyses.

## Results and Discussion

**Growth Data.** From 80 to 160 lb BW, pigs fed the diets with CLA had reduced (P = .03) ADG when compared to pigs fed the control diet (Table 3). Otherwise, the means of pigs fed either MTO or CLA did not differ (P > .15) from those of pigs fed the control diet during either growth phase or on a cumulative basis for ADG, ADFI, or F/G.

However, a difference in growth performance occurred between pigs fed MTO and CLA. Pigs fed MTO grew faster during the 80 to 160 (P < .01), 160 to 230 (P = .10), and 80 to 230 (P = .03) lb BW growth intervals than pigs fed CLA. This is attributable to nonsignificant improvements in ADFI and F/G from 80 to 160 lb BW and to a higher ADFI from 160 to 230 lb BW (P = .06) and overall (P = .10) ADFI for pigs fed MTO.

**Carcass Characteristics.** No effect of dietary treatment (P>.15) was observed for any of the measured carcass quality criteria (Table 4).

**Serum Chemistry.** The feeding of MTO or CLA to pigs did not affect (P>.20) fasted serum TG levels (Table 4).

In this study, supplementing diets fed to pigs with MTO or CLA did not have beneficial effects in terms of growth performance, carcass composition, or serum TG levels. However, both pigs fed the control diet and pigs fed MTO had good overall growth performance. Additionally, pigs fed CLA or MTO were similar in carcass quality, and both were numerically better than the control group.

Some differences exist between the two feed additives. Tonalin™ CLA 60 is a byproduct of the sunflower oil extraction industry, whereas the MTO used in this experiment is a byproduct of the kraft paper process. Neither CLA nor MTO is currently approved for use as a feed additive in swine diets.

The differences observed in the growth performance of pigs fed MTO and CLA are not readily explainable. The MTO was entirely unsaturated, whereas the CLA contained a large amount of saturated fatty acids (< 12%). However, the data do imply that the *cis* 9, *trans* 11 form of CLA may not be the biologically active form. Diets containing MTO and CLA each had similar amounts of this isomer, but the diet containing MTO produced significantly better ADG. Several explanations are possible for the different biological response: 1) the different isomeric profiles of the fatty acids in the two compounds; 2) the large amount of saturated fatty acids present in CLA; 3) the larger relative concentration of actual conjugated linoleic acids present in MTO (+ ~ 15%); or 4) an isomer in higher concentration in MTO (i.e., *trans* 9, *trans* 11).

In conclusion, more research is needed to determine if MTO can be used as an effective growth promotant and carcass modifier for swine. However, the results of this study do indicate that pigs fed MTO had greater ADG than those fed CLA.

**Table 1. Compositions of Soybean Oil, Modified Tall Oil, and Conjugated Linoleic Acid[a]**

| Item | Soybean Oil | MTO (Kraft paper process) | Tonalin™ CLA 60 (Sunflower-derived) |
|---|---|---|---|
| Unsaponifiables, % max | N/A | 2.8 | 1.0 |
| Iodine value[b] | 130 | 162 | 139 |
| Specific gravity | N/A | 0.91 | 0.92 |
| Acid value, mg KOH/g | N/A | 195 | 199 |
| Fatty acid composition, % | | | |
| Conjugated linoleic acid | ---- | 69 | 58.4 |
| Total linoleic acid | 52 | 78 | 64.9 |
| Oleic acid | 25 | 22 | 22.7 |
| Saturated fatty acids | 16 | <1 | 12.3 |

| | Chemical Analyses[c] | | |
|---|---|---|---|
| Item, % | Soybean oil[d] | Pamolyn MTO | Tonalin™ CLA 60 |
| Palmitic acid, 16:0 | 15.96 | 0.46 | 7.65 |
| Stearic acid, 18:0 | 4.11 | 0.07 | 5.15 |
| Oleic acid, 18:1 | 20.34 | 19.84 | 24.73 |
| Linoleic acid, 18:2 (*c*9, *c*12) | 50.65 | 2.29 | 4.81 |
| CLA, 18:2 | | | |
| *c*&*t*, 9, 11 mix | ND[e] | 20.52 | 21.33 |
| *t*9, *t*11 | ND | 14.80 | 3.90 |
| *c*10, *c*12 | ND | 13.98 | 10.38 |
| *t*10, *c*12 | ND | 14.37 | 16.40 |
| 3 CLA peaks | ND | 8.83 | 3.79 |
| Unknown | ND | 4.83 | 1.85 |
| Total CLAs | ND | 72.50 | 55.80 |
| Total | 91.06 | 100.00 | 100.00 |

[a]Values for the products are guaranteed analyses from the companies providing the products and represent the minimum or maximum value when specified or the average when a range of values was given.
[b]A measure of the degree of unsaturation of fats and oils.
[c]Analyses were conducted at Kansas State University using gas chromatography.
[d]Soybean oil contains small amounts of myristic acid (14:0), linolenic acid (18:3), and eicosenoic acid (20:1), which were not present in the CLA and MTO samples. This accounts for soybean oil not adding to 100%.
[e]Not detectable.

**Table 2. Composition of Basal Diets (As-Fed Basis)**

| Ingredient, % | Grower[a] | Finisher[b] |
|---|---|---|
| Corn | 69.29 | 78.63 |
| Soybean meal (46.5% CP) | 27.47 | 18.39 |
| Limestone | 1.06 | .89 |
| Monocalcium phosphate | .85 | .76 |
| Soybean oil[c] | .50 | .50 |
| Salt | .35 | .35 |
| Vitamin premix | .20 | .20 |
| Trace mineral premix | .15 | .15 |
| Antibiotic[d] | .13 | .13 |
| Total | 100.00 | 100.00 |

[a]Grower diets were fed from 80 to 160 lb BW and were formulated to contain 1.00% lysine, .65% Ca, and .55% total P.
[b]Finisher diets were fed from 160 to 230 lb BW and were formulated to contain .75% lysine, .55% Ca, and .50% total P.
[c]Soybean oil was substituted on an equal basis with MTO and CLA to give the three experimental treatments.
[d]Provided 100 g/ton tylosin.

**Table 3. Growth Performance of Barrows Fed Modified Tall Oil or Conjugated Linoleic Acid[a]**

| | | | | | Contrast Probability Values (P<) | | |
|---|---|---|---|---|---|---|---|
| Item | Control (1) | MTO (2) | CLA (3) | CV | 1 vs 2 | 1 vs 3 | 2 vs 3 |
| 80 to 160 lb | | | | | | | |
| ADG, lb | 2.30 | 2.35 | 2.17 | 4.24 | .35 | .03 | <.01 |
| ADFI, lb | 5.78 | 5.79 | 5.57 | 5.63 | .93 | .28 | .25 |
| F/G | 2.51 | 2.46 | 2.57 | 5.04 | .49 | .43 | .15 |
| 160 to 230 lb | | | | | | | |
| ADG, lb | 2.26 | 2.37 | 2.11 | 11.4 | .44 | .35 | .10 |
| ADFE, lb | 7.14 | 7.45 | 6.72 | 8.95 | .41 | .27 | .06 |
| F/G | 3.17 | 3.14 | 3.21 | 7.50 | .79 | .80 | .61 |
| 80 to 230 lb | | | | | | | |
| ADG, lb | 2.28 | 2.36 | 2.14 | 7.28 | .39 | .17 | .03 |
| ADFI, lb | 6.44 | 6.60 | 6.13 | 7.30 | .56 | .27 | .10 |
| F/G | 2.83 | 2.79 | 2.87 | 5.14 | .64 | .62 | .34 |

[a]Values are means for two pigs/pen and six replicate pens/treatment.

**Table 4. Carcass Characteristics of Barrows Fed Modified Tall Oil or Conjugated Linoleic Acid[a,b,c]**

| | | | | | Contrast Probability Values (P<) | | |
|---|---|---|---|---|---|---|---|
| Item | Control (1) | MTO (2) | CLA (3) | CV | 1 vs 2 | 1 vs 3 | 2 vs 3 |
| Shrink loss, % | 2.12 | 2.18 | 2.17 | 8.68 | .55 | .47 | .77 |
| Backfat, in | | | | | | | |
| First rib | 1.45 | 1.35 | 1.37 | 9.15 | .21 | .38 | .93 |
| Tenth rib | .92 | .87 | .87 | 16.89 | .57 | .34 | .59 |
| Last rib | .77 | .72 | .72 | 10.81 | .31 | .68 | .71 |
| Last lumbar | .77 | .77 | .71 | 11.56 | .99 | .83 | .82 |
| Average[d] | .98 | .93 | .93 | 7.27 | .24 | .36 | .98 |
| LMA, $in^2$ | 5.68 | 5.67 | 5.45 | 7.68 | .97 | .23 | .22 |
| Lean %[e] | 50.95 | 51.35 | 51.15 | 4.65 | .77 | .34 | .45 |
| Dressing % | 72.65 | 72.32 | 71.61 | 1.31 | .57 | .61 | .93 |
| Visual color[f] | 2.65 | 2.50 | 2.60 | 7.28 | .20 | .39 | .90 |
| Firmness[f] | 3.18 | 3.07 | 3.15 | 21.70 | .78 | .65 | .51 |
| Marbling[f] | 2.48 | 2.83 | 2.82 | 19.05 | .27 | .26 | .76 |
| Hunter L*[g] | 50.93 | 52.70 | 52.66 | 6.14 | .53 | .65 | .47 |
| Hunter a*[g] | 10.80 | 11.00 | 12.01 | 25.53 | .93 | .99 | .96 |
| Hunter b*[g] | 7.00 | 7.57 | 7.89 | 29.31 | .76 | .82 | .71 |
| Hue angle[g] | 43.86 | 48.60 | 44.92 | 9.84 | .27 | .79 | .37 |
| Saturation index[g] | 13.11 | 13.36 | 14.39 | 22.80 | .93 | .64 | .71 |
| A:B ratio[g] | 1.55 | 1.45 | 1.53 | 7.28 | .33 | .79 | .45 |
| Drip loss, % | 3.03 | 2.98 | 2.83 | 43.00 | .93 | .21 | .23 |
| Triglycerides[h] | 33.33 | 40.17 | 41.17 | 29.58 | .32 | .26 | .88 |

[a]Values are means for two pigs/pen and six replicate pens/treatment.
[b]Hot carcass weight was used as a covariate in the statistical analysis.
[c]Carcass length (mean = 31.98 in) and muscle score (mean = 2.53) were not affected (P > .15) by dietary treatment.
[d]Average backfat is the average of the first and last rib and last lumbar fat depths.
[e]Lean percentage was derived from NPPC equations with 5% fat.
[f]Scoring system of 1 to 5: 2 = grayish pink, traces to slight, or soft and watery; 3 = reddish pink, small to modest, or slightly firm and moist; and 4 = purplish red, moderate to slightly abundant, or firm and moderately dry for color, firmness, and marbling, respectively.
[g]Means were derived from three sample readings per loin. Measures of dark to light (Hunter L*), redness (Hunter a*), yellowness (Hunter b*), red to orange (hue angle), or vividness or intensity (saturation index).
[h]Values represent the pooled results of both pigs/pen bled the day before slaughter, and triglyceride levels are expressed as mg/dL.

# EFFECTS OF LEVEL OF MODIFIED TALL OIL ON FINISHING PIG GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS[1]

***P. R. O'Quinn, J. L. Nelssen, M. D. Tokach[2], R. D. Goodband, J. C. Woodworth, and J. A. Unruh***

## Summary

A growth trial was conducted to evaluate effects of increasing levels of modified tall oil (MTO) on growth performance and carcass composition of finishing barrows. No effect of treatment was observed for ADG, ADFI, or feed efficiency (F/G) during any of the growth periods. However, pigs fed increasing MTO had less backfat, larger longissimus muscle area, and increased percentage muscle than control pigs not fed MTO. Additionally, carcasses from pigs fed MTO had decreased drip loss. The results of this trial indicate that although MTO has no impact on growth performance in barrows, it can improve carcass leanness. The optimal dose level for the MTO appears to be about .50% of the diet.

(Key Words: Barrows, Modified Tall Oil, Growth Performance, Carcass Merit.)

## Introduction

Tall oil is a nonaqueous layer of rosin acids and fatty acids produced during the kraft (sulfate) paper process. In a pilot study (pg. 157), pigs fed modified tall oil (MTO) grew faster and consumed more feed than pigs fed conjugated linoleic acid (CLA). Additionally, pigs fed MTO or CLA had equal carcass composition indicating that, although MTO and CLA have similar intrinsic properties, their modes of action may be very dissimilar. Thus, a dose-titration assay was conducted to determine the optimal level of MTO to maximize pig growth performance and carcass composition.

## Procedures

A total of 80 crossbred barrows (initially 74 lb; PIC L326 × C22) was blocked on the basis of initial weight and ancestry and randomly allotted to four dietary treatments with 10 replicate pens per treatment.

All diets were pelleted (3/16 in diameter). Diets were fed in two phases (75 to 160 and 160 to 260 lb BW; Table 1), and diets were changed when the average weight of pigs in a replication of pens reached 160 lb. Modified tall oil was substituted on a wt/wt basis for cornstarch in the experimental diets.

Pigs were housed in an environmentally controlled finishing barn with two pigs in each 4 ft × 4 ft pen with a totally slatted floor. Pigs were allowed ad libitum access to feed and water through one single-hole self-feeder and a nipple waterer. Pigs were weighed every 14 d in order to determine ADG, ADFI, and feed efficiency (F/G). The

[1]Appreciation is extended to Lonza Inc., Fair Lawn, NJ, for partial financial support of this research, Hercules Inc., Wilmington, DE, for providing the modified tall oil, and Joel Englen, Ann Waylan, Carrie George, and Tim Clark for help in fabricating the carcasses and collecting carcass and belly firmness data. Appreciation also is extended to Colin Bradley of the London Health Sciences Centre, London, Ontario, Canada, for conducting the triglyceride assays.

[2]Northeast Area Extension Office, Manhattan, KS.

day before slaughter, plasma blood samples were collected from each pig for analysis of triglyceride (TG) concentrations following a 3 h fast. The TG results later were combined for each pen for statistical analysis.

Pigs were slaughtered when the average weight of pigs in a pen reached 260 lb. Standard carcass measurements; visual analyses of the longissimus for coloring, marbling, and firmness; longissimus drip loss, and Minolta colorspectrometry (Hunter L*, a*, and b*) were determined for each pig at 24 h postmortem (drip loss = 48 h postmortem). During fabrication of the carcasses (24 h postmortem), the bellies from the right sides of all carcasses were removed and evaluated for firmness.

Data were analyzed as a randomized complete block. Pen was the experimental unit for all calculations. The IML procedure of SAS was used to generate the necessary orthogonal polynomial contrast coefficients needed for the GLM procedures of SAS. Thus, despite the unequally spaced treatment design, all data were analyzed using the GLM procedures. Hot carcass weight was used as a covariate for the carcass analysis. Additionally, weight and length of the bellies were used as covariates for the analysis of belly firmness.

## Results and Discussion

**Growth Data.** No effects of treatment (P>.15) were observed for ADG, ADFI, or F/G during any of the growth intervals (75 to 160, 160 to 260, and 75 to 260 lb BW; Table 2). We should note that all pigs had good growth performance despite the trial being conducted during the summer months of June to September.

**Carcass Characteristics.** Pigs fed increasing MTO had reduced (quadratic, P<.05) first, last, and tenth rib; last lumbar; and average backfat depths as compared to control pigs (Table 3). Pigs fed MTO also tended (quadratic, P = .07) to have larger longissimus muscle area. The reduced backfat and larger longissimus muscle area resulted in a higher (quadratic, P = .03) lean percentage for the MTO-supplemented pigs. Drip loss was reduced (quadratic, P = .04) by increasing MTO. These quadratic responses are due to a plateau effect where little or no benefit occurred from increasing MTO concentrations above 0.50% of the diet.

Pigs fed the control diet had longissimus muscles that were redder and more intensely colored (linear, P = .04) and more yellow (linear, P = .07) than those from pigs supplemented with MTO. Although these were linear effects, when they were plotted, they seemed to be due to the control diet producing different results than any of the MTO diets. Although not significant (P>.20), this same function appears to hold true for belly firmness. The average belly firmness was 18% greater for MTO-fed pigs than for the control-fed pigs. Carcass length and visual degree of muscling were decreased linearly ($P \leq .05$) by increasing MTO, although this may not be practically important because of the small absolute differences.

**Serum Chemistry.** Feeding MTO to pigs did not affect (P>.35) fasted serum TG levels (Table 3).

The exact mode of action for the positive benefits of MTO upon the body are not fully understood. Research is currently underway to examine the multitude of beneficial roles that MTO may play in swine production.

The results of this trial indicate that, although MTO has no impact on growth performance in barrows, it can improve carcass leanness. The optimal dose level for the MTO appears to be about .50% of the diet.

**Table 1. Composition of Basal Diets (As-Fed Basis)**

| Ingredient, % | Grower[a] | Finisher[b] |
|---|---|---|
| Corn | 68.76 | 78.08 |
| Soybean meal (46.5% CP) | 27.50 | 18.43 |
| Limestone | 1.05 | .88 |
| Cornstarch[c] | 1.00 | 1.00 |
| Monocalcium phosphate | .86 | .78 |
| Salt | .35 | .35 |
| Vitamin premix | .20 | .20 |
| Trace mineral premix | .15 | .15 |
| Antibiotic[d] | .13 | .13 |
| Total | 100.00 | 100.00 |

[a]Grower diets were fed from 75 to 160 lb BW and were formulated to contain 1.00% lysine, .65% Ca, and .55% total P.
[b]Finisher diets were fed from 160 to 260 lb BW and were formulated to contain .75% lysine, .55% Ca, and .50% total P.
[c]Modified tall oil was substituted for cornstarch on an equal weight basis at .25, .50, and 1.00% of the diet to provide the three experimental treatments.
[d]Provided 100 g/ton tylosin.

**Table 2. Growth Performance of Barrows Fed Increasing Modified Tall Oil[a]**

| | Modified Tall Oil, % | | | | | Probability Values | |
|---|---|---|---|---|---|---|---|
| Item | 0 | .25 | .50 | 1.00 | CV | Linear | Quadratic |
| 75 to 160 lb | | | | | | | |
| ADG, lb | 2.38 | 2.35 | 2.40 | 2.35 | 6.64 | .77 | .73 |
| ADFI, lb | 5.23 | 5.12 | 5.09 | 5.17 | 5.87 | .40 | .51 |
| F/G | 2.20 | 2.19 | 2.12 | 2.20 | 4.81 | .57 | .21 |
| 160 to 260 lb | | | | | | | |
| ADG, lb | 2.17 | 2.15 | 2.18 | 2.14 | 7.82 | .85 | .89 |
| ADFI, lb | 6.59 | 6.52 | 6.53 | 6.31 | 6.51 | .93 | .43 |
| F/G | 3.04 | 3.05 | 2.99 | 2.96 | 6.02 | .70 | .29 |
| 75 to 260 lb | | | | | | | |
| ADG, lb | 2.27 | 2.23 | 2.28 | 2.23 | 5.74 | .71 | .79 |
| ADFI, lb | 5.98 | 5.89 | 5.89 | 5.80 | 5.67 | .79 | .44 |
| F/G | 2.64 | 2.64 | 2.58 | 2.60 | 4.54 | .88 | .19 |

[a]Values are means for two pigs/pen and 10 replicate pens/treatment.

**Table 3. Carcass Characteristics of Barrows Fed Increasing Modified Tall Oil[a,b]**

| | Modified Tall Oil, % | | | | | Probability Values | |
|---|---|---|---|---|---|---|---|
| Item | 0 | .25 | .50 | 1.00 | CV | Linear | Quadratic |
| Shrink loss, % | 1.99 | 2.03 | 2.03 | 2.09 | 5.12 | .71 | .20 |
| Backfat, in. | | | | | | | |
| First rib | 1.51 | 1.52 | 1.44 | 1.47 | 8.61 | .74 | .13 |
| Tenth rib | .88 | .83 | .76 | .77 | 17.17 | .82 | .04 |
| Last rib | .96 | .99 | .91 | .91 | 9.50 | .19 | .04 |
| Last lumbar | .85 | .80 | .76 | .74 | 12.34 | .75 | .02 |
| Average[c] | 1.10 | 1.10 | 1.04 | 1.04 | 7.73 | .60 | .02 |
| LMA, $in^2$ | 6.39 | 6.51 | 6.73 | 6.74 | 7.45 | .80 | .07 |
| Lean %[d] | 51.79 | 52.52 | 53.59 | 53.69 | 3.69 | .83 | .03 |
| Dressing % | 74.29 | 73.63 | 73.69 | 73.31 | 1.09 | .27 | .11 |
| Visual color[e] | 2.35 | 2.53 | 2.35 | 2.39 | 11.38 | .19 | .49 |
| Firmness[e] | 2.40 | 2.65 | 2.63 | 2.64 | 12.73 | .21 | .27 |
| Marbling[e] | 2.18 | 2.38 | 2.30 | 2.39 | 13.34 | .30 | .41 |
| Hunter L*[f] | 55.08 | 53.78 | 53.49 | 55.03 | 4.80 | .22 | .52 |
| Hunter a*[f] | 13.95 | 12.25 | 11.92 | 13.27 | 13.67 | .04 | .12 |
| Hunter b*[f] | 12.13 | 8.47 | 8.27 | 9.50 | 39.65 | .07 | .14 |
| Hue angle[f] | 48.05 | 48.37 | 48.11 | 50.41 | 12.76 | .87 | .75 |
| Saturation index[f] | 19.21 | 14.91 | 14.53 | 16.34 | 24.37 | .04 | .09 |
| A:B ratio[f] | 1.39 | 1.46 | 1.47 | 1.41 | 7.07 | .16 | .40 |
| Drip loss, % | 5.17 | 4.99 | 3.60 | 4.95 | 32.63 | .64 | .04 |
| Carcass length, in | 33.35 | 32.70 | 32.86 | 33.02 | 1.80 | .03 | .42 |
| Muscling | 2.55 | 2.45 | 2.50 | 2.50 | 4.05 | .05 | .73 |
| Belly firmness | | | | | | | |
| Initial[g] | 9.24 | 11.05 | 10.88 | 11.92 | 27.16 | .39 | .23 |
| 1 min[g] | 8.60 | 10.30 | 10.12 | 11.16 | 27.29 | .39 | .22 |
| 5 min[g] | 8.05 | 9.70 | 9.01 | 10.09 | 29.98 | .36 | .53 |
| Triglycerides[h] | 29.50 | 28.12 | 31.36 | 30.42 | 24.88 | .64 | .39 |

[a]Values are means for two pigs/pen and six replicate pens/treatment.
[b]Hot carcass weight was used as a covariate in the statistical analysis.
[c]Average backfat is the average of the first and last rib and last lumbar fat depths.
[d]Lean percentage was derived from NPPC equations with 5% fat.
[e]Scoring system of 1 to 5: 2 = grayish pink, traces to slight, or soft and watery; 3 = reddish pink, small to modest, or slightly firm and moist; and 4 = purplish red, moderate to slightly abundant, or firm and moderately dry for color, firmness, or marbling, respectively.
[f]Means were derived from three sample readings per loin. Measures of dark to light (Hunter L*), redness (Hunter a*), yellowness (Hunter b*), red to orange (hue angle), or vividness or intensity (saturation index).
[g]Belly firmness scores refer to the degree of droop (inches) when the bellies were centrally suspended by a bar. Thus, larger values indicate firmer bellies. Belly length and weight were used as covariates for this portion of the statistical analysis.
[h]Values represent the pooled results of both pigs/pen bled the day before slaughter and triglyceride levels are expressed as mg/dL.

# EFFECTS OF SOURCE AND LEVEL OF ADDED CHROMIUM ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF GROWING-FINISHING PIGS [1,2]

***P. R. O'Quinn, J. W. Smith, II, J. L. Nelssen, M. D. Tokach [3], R. D. Goodband, K. Q. Owen[4], and S. A. Blum***

## Summary

A growth trial was conducted to evaluate the effects of added chromium nicotinate (CrNic) on growth performance and carcass composition of growing-finishing pigs (80 to 230 lb) and to compare 200 ppb of CrNic and chromium picolinate (CrPic). Few statistical responses were observed for growth performance, carcass characteristics, or serum chemistry profiles. These data suggest no beneficial responses to supplemental chromium in diets for growing-finishing barrows and gilts.

(Key Words: Growing-Finishing Pigs, Chromium Nicotinate, Growth, Carcass Quality.)

## Introduction

Chromium is a trace mineral that is involved actively in the metabolism of carbohydrates, lipids, proteins, and nucleic acids in the body. Chromium is most widely recognized as a potentiator of the actions of insulin. In animal studies, Cr supplementation is reported to increase rate and efficiency of gain and degree of muscling and decrease fat deposition. Chromium also is thought to improve the immune status in stressed animals. Several forms of Cr have been evaluated in swine studies, including yeast cultures, chromium chloride, and CrPic, which has received the most attention in the scientific literature. Recent chromium work with human subjects has suggested that CrNic may be more biologically available than CrPic. For these reasons, a feeding trial was designed to evaluate the efficacy of CrNic supplementation and to compare growth performance and carcass characteristics of pigs fed equal concentrations of CrNic and CrPic.

## Procedures

A total of 144 crossbred barrows and gilts (initially 80.7 lb) was used in the growth trial. Pigs were blocked on the basis of initial weight, sex, and ancestry and randomly allotted to dietary treatments with six replications per sex per treatment.

All diets were fed in meal form (Table 1). Barrows and gilts were fed separate diets within each phase to more accurately meet changes in their lysine requirements. All diets contained .1% L-lysine•HCl. Diets were fed in three phases (80 to 130, 130 to 180, and 180 to 230 lb BW), and diets were changed when the average weight of pigs in a pen reached the upper limit of the weight interval. Chromium was added to the basal diets at 50, 100, 200, or 400 ppb Cr as CrNic or 200 ppb Cr as CrPic. The Cr additions first were prepared as a 20-lb premix and then blended

[1]Appreciation is extended to Lonza Inc., Fair Lawn, NJ for partial financial support and for providing the chromium nicotinate used in this experiment.

[2]The authors thank Colin Bradley of the London Health Sciences Centre, London, Ontario, Canada, for conducting the serum and dietary chromium analyses.

[3]Northeast Area Extension Office, Manhattan, KS.

[4]Lonza Inc., Fair Lawn, NJ.

with the other dietary ingredients to ensure proper mixing.

Pigs were housed in an environmentally controlled finishing barn with two pigs in each 5-ft × 5-ft totally slatted-floored pen. Pigs were allowed ad libitum access to feed and water through one single-hole self-feeder and a nipple waterer.

Pigs were weighed every 2 weeks to determine ADG, ADFI, and feed efficiency (F/G). The day before slaughter, blood samples were taken from each pig to determine serum Cr concentrations after a 3-h fast. Blood samples were pooled for each pen and stored frozen until the analyses were conducted.

Pigs were slaughtered when the average weight of pigs in a pen reached 230 lb. Standard carcass measurements; visual analyses of the longissimus for coloring, marbling, and firmness; drip loss; and Minolta colorspectrometry (Hunter L*, a*, and b*) were taken for each pig 24-h postmortem (drip loss at 48-h postmortem).

Data were analyzed as a randomized complete block. The pen was the experimental unit for all calculations. The trial was analyzed as two separate experiments (one for barrows and one for gilts) because of the different lysine levels fed to barrows and gilts. Because of the unequal spacing of dietary chromium concentrations, a regression model was fit to the data. Thus, the REG procedure of SAS was used to determine the linear and quadratic effects of supplementation with CrNic, whereas the GLM procedure of SAS was used for the single degree of freedom contrast between pigs fed 200 ppb CrNic and 200 ppb CrPic and between pigs fed the control diet and the diet containing 200 ppb CrPic. No covariates were used in the statistical model for the carcass analyses because of the similar ending test weight of all pigs.

## Results and Discussion

**Growth Data.** From 130 to 180 lb, increasing CrNic tended (linear, P = .09) to decrease ADG in barrows (Table 2). This resulted in an overall (80 to 230 lb) tendency for decreased ADG (linear, P = .09) for pigs fed increasing CrNic. Otherwise, neither source of Cr nor level of increasing CrNic had an effect (P>.10) on ADG, ADFI, or F/G for any of the growth intervals or the total trial.

Neither source of Cr nor level of increasing CrNic had any effect (P>.20) on gilt growth performance during any of the growth intervals or over the entire trial. Although not compared statistically, gilts fed 50 ppb Cr as CrNic grew on average 7% faster and converted feed to gain approximately 5% better than did control gilts.

**Carcass Characteristics.** Other than a quadratic response (P = .10) in last lumbar backfat, neither source of Cr nor level of increasing CrNic had any effect (P>.10) on carcass characteristics for barrows (Table 4).

Gilts fed increasing levels of CrNic had greater first rib fat depths (linear, quadratic, P<.05; Table 5) than control gilts. Chromium source affected (P = .05) longissimus muscle visual color, with gilts fed 200 ppb CrPic having a darker colored longissimus muscle than gilts fed 200 ppb CrNic. Drip loss percentage in gilts was increased (P = .02) with increased CrNic supplementation. An explanation for this response is not readily apparent, because Cr has no known function with membrane permeability. The effects of supplemental Cr on longissimus muscle quality were not consistent.

**Serum Analysis.** Source of Cr affected barrow serum Cr levels (Table 6), with barrows fed CrPic having a higher (P = .05) concentration than CrNic-supplemented barrows. Neither source of Cr nor level of increasing CrNic had an effect (P>.10) on gilt serum Cr concentrations (Table 6).

**General.** Differences between pigs fed the control diets or the diets containing 200 ppb CrPic were few. Barrows fed 200 ppb CrPic grew slower (P = .02) from 180 to 230 lb BW. Gilts fed 200 ppb CrPic ate more feed (P = .04) from 130 to 180 lb BW. Gilts

fed the control diet had more marbled longissimus muscle (P = .02) and a higher drip loss (P = .07) than pigs fed the 200 ppb CrPic diet. Barrows fed 200 ppb CrPic had a higher (P = .03) serum Cr level than pigs fed the control diet.

Dietary chromium is absorbed from the GI tract, converted to trivalent Cr upon entry into the bloodstream, and rapidly taken up into the tissues. Because the blood and tissue levels of Cr are not in equilibrium, serum values may not be good indicators of Cr status. Any Cr not used or stored by the tissues is excreted back to the blood for excretion from the body via the urine. Thus, 24-hr urinary Cr measurements may be better indicators of Cr stores than serum Cr levels are.

Two small assays were undertaken later to help explain some of the serum Cr differences noted herein and in an earlier nursery trial with CrNic and CrPic. First, 20 finishing weight pigs from a commercial farm in Northeast Kansas were bled for serum Cr analysis. This farm had never fed Cr through any of their barns. The mean value for these pigs was 11.17 ± 3.63 nmol/L of Cr (data not shown). This value is considerably lower than that for the control pigs not fed Cr in the present experiment. These results could indicate a difference in Cr content of the dietary ingredients. The diets fed on this farm were typical grain-soybean meal-based diets, but they were not assayed for Cr content.

Secondly, analysis of such diets not containing supplemental Cr indicated that background Cr levels range well into the ppm range (data not shown). No work has been conducted to define the bioavailability of this background Cr. Even if only a small fraction is bioavailable, the high levels could mask any potential treatment responses, especially when dietary inclusion levels are only in the low-to-mid ppb range.

In conclusion, supplemental Cr (either as CrNic or CrPic) had no beneficial effects on growth performance or carcass characteristics of growing-finishing pigs. Because of consistent numerical improvements in ADG and F/G with gilts fed 50 ppb Cr as CrNic, further research should be conducted to evaluate lower concentrations of CrNic in diets fed to finishing gilts. These results further suggest that the responses to supplemental Cr may be related directly to the level of background Cr already present in the diet.

**Table 1. Composition of Basal Diets (As-Fed Basis)[a]**

| | Period I[b] | | Period II[c] | | Period III[d] | |
|---|---|---|---|---|---|---|
| Ingredient, % | Barrows | Gilts | Barrows | Gilts | Barrows | Gilts |
| Corn | 70.09 | 66.52 | 78.02 | 74.46 | 83.65 | 80.08 |
| Soybean meal, 46.5% CP | 24.77 | 28.39 | 17.47 | 21.09 | 12.02 | 15.64 |
| Soybean oil | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Monocalcium phosphate | 1.15 | 1.09 | .80 | .73 | .65 | .59 |
| Limestone | 1.06 | 1.07 | .88 | .89 | .85 | .86 |
| Vitamin/trace mineral premix | .35 | .35 | .25 | .25 | .25 | .25 |
| Salt | .35 | .35 | .35 | .35 | .35 | .35 |
| Antibiotic[e] | .13 | .13 | .13 | .13 | .13 | .13 |
| L-Lysine•HCl | .10 | .10 | .10 | .10 | .10 | .10 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

[a]Graded levels of Cr were added to the basal diets to achieve levels of 50, 100, 200, or 400 ppb Cr. [b]Period I diets were fed from 80 to 130 lb BW and were formulated to contain .70% total Ca, .60% total P, and either 1.00% (barrows) or 1.10% (gilts) lysine. [c]Period II diets were fed from 130 to 180 lb BW and were formulated to contain .55% total Ca, .50% total P, and either .80% (barrows) or .90% (gilts) lysine. [d]Period III diets were fed from 180 to 230 lb BW and were formulated to contain .50% total Ca, .45% total P, and either .65% (barrows) or .75% (gilts) lysine. [e]Provided 100 g/ton tylosin.

**Table 2. Growth Performance of Barrows Fed Graded Levels of Chromium[a]**

| | CrNic | | | | | CrPic | | Probability | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | 0 | 50 | 100 | 200 | 400 | 200 | CV | Lin.[b] | Quad.[b] | Cont.[c] |
| 80 to 130 lb BW | | | | | | | | | | |
| ADG, lb | 2.37 | 2.50 | 2.27 | 2.27 | 2.42 | 2.30 | 8.46 | .15 | .14 | .23 |
| ADFI, lb | 5.53 | 5.75 | 5.40 | 5.56 | 5.54 | 5.34 | 7.73 | .78 | .82 | .95 |
| F/G | 2.34 | 2.31 | 2.38 | 2.44 | 2.30 | 2.33 | 6.81 | .14 | .12 | .13 |
| 130 to 180 lb BW | | | | | | | | | | |
| ADG, lb | 2.62 | 2.54 | 2.35 | 2.44 | 2.45 | 2.40 | 8.87 | .09 | .14 | .96 |
| ADFI, lb | 7.33 | 7.38 | 6.92 | 7.08 | 7.02 | 6.88 | 8.40 | .32 | .45 | .86 |
| F/G | 2.81 | 2.91 | 2.96 | 2.90 | 2.89 | 2.87 | 8.38 | .46 | .47 | .92 |
| 180 to 230 lb BW | | | | | | | | | | |
| ADG, lb[d] | 2.37 | 2.39 | 2.27 | 2.27 | 2.08 | 2.29 | 9.15 | .54 | .88 | .14 |
| ADFI, lb | 7.80 | 7.97 | 7.41 | 7.74 | 7.41 | 7.90 | 8.17 | .70 | .95 | .37 |
| F/G | 3.30 | 3.34 | 3.26 | 3.44 | 3.57 | 3.46 | 8.68 | .82 | .76 | .44 |
| 80 to 230 lb BW | | | | | | | | | | |
| ADG, lb | 2.45 | 2.49 | 2.30 | 2.32 | 2.33 | 2.34 | 6.98 | .09 | .18 | .93 |
| ADFI, lb | 6.89 | 7.03 | 6.58 | 6.79 | 6.66 | 6.71 | 7.20 | .51 | .68 | .64 |
| F/G | 2.81 | 2.83 | 2.86 | 2.92 | 2.86 | 2.87 | 5.19 | .16 | .22 | .48 |

[a]Values are means for two pigs/pen and six replications/treatment.
[b]Contrasts refer to the linear and quadratic comparisons of CrNic supplementation.
[c]Contrast refers to the comparison of supplementation with 200 ppb CrNic against that of 200 ppb CrPic.
[d]Control differs from 200 ppb CrPic (P = .02). All other contrasts between the control diets and diets containing 200 ppb CrPic were nonsignificant (P>.10).

**Table 3. Growth Performance of Gilts Fed Graded Levels of Chromium[a]**

| | CrNic | | | | | CrPic | | Probability | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | 0 | 50 | 100 | 200 | 400 | 200 | CV | Lin.[b] | Quad.[b] | Cont.[c] |
| 80 to 130 lb BW | | | | | | | | | | |
| ADG, lb | 2.05 | 2.25 | 2.12 | 2.14 | 2.10 | 2.21 | 6.45 | .47 | .41 | .65 |
| ADFI, lb | 4.88 | 5.16 | 5.07 | 4.85 | 4.85 | 5.08 | 5.17 | .94 | .68 | .99 |
| F/G | 2.39 | 2.30 | 2.40 | 2.27 | 2.31 | 2.29 | 4.96 | .32 | .45 | .59 |
| 130 to 180 lb BW | | | | | | | | | | |
| ADG, lb | 2.18 | 2.34 | 2.20 | 2.02 | 2.10 | 2.14 | 9.39 | .27 | .47 | .54 |
| ADFI, lb[d] | 6.10 | 6.16 | 6.12 | 5.71 | 5.73 | 6.20 | 5.35 | .19 | .51 | .92 |
| F/G | 2.83 | 2.65 | 2.78 | 2.83 | 2.75 | 2.90 | 8.65 | .87 | .86 | .57 |
| 180 to 230 lb BW | | | | | | | | | | |
| ADG, lb | 2.14 | 2.23 | 2.15 | 2.08 | 2.06 | 2.18 | 10.74 | .77 | .98 | .86 |
| ADFI, lb | 6.35 | 6.91 | 6.61 | 6.47 | 6.29 | 6.91 | 6.77 | .58 | .35 | .50 |
| F/G | 3.01 | 3.13 | 3.09 | 3.13 | 3.06 | 3.17 | 8.79 | .47 | .47 | .67 |
| 80 to 230 lb BW | | | | | | | | | | |
| ADG, lb | 2.11 | 2.27 | 2.15 | 2.07 | 2.08 | 2.17 | 7.03 | .66 | .90 | .86 |
| ADFI, lb | 5.78 | 6.08 | 5.94 | 5.68 | 5.63 | 6.06 | 4.01 | .77 | .70 | .71 |
| F/G | 2.76 | 2.68 | 2.76 | 2.75 | 2.70 | 2.79 | 5.91 | .79 | .72 | .60 |

[a]Values are means for two pigs/pen and six replications/treatment.
[b]Contrasts refer to the linear and quadratic comparisons of CrNic supplementation.
[c]Contrast refers to the comparison of supplementation with 200 ppb CrNic against that of 200 ppb CrPic.
[d]Control differs from 200 ppb CrPic (P = .04). All other contrasts between the control diets and diets containing 200 ppb CrPic were nonsignificant (P>.20).

**Table 4. Carcass Characteristics of Barrows Fed Graded Levels of Chromium[a,b]**

| | CrNic | | | | | CrPic | | Probability | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | 0 | 50 | 100 | 200 | 400 | 200 | CV | Lin.[c] | Quad.[c] | Cont.[d,e] |
| Shrink loss, % | 2.70 | 2.59 | 2.54 | 2.39 | 2.39 | 2.30 | 15.50 | .16 | .34 | .96 |
| Backfat, in: | | | | | | | | | | |
| First rib | 1.50 | 1.52 | 1.59 | 1.52 | 1.51 | 1.53 | 5.34 | .40 | .34 | .89 |
| Tenth rib | .94 | .96 | .98 | .90 | .93 | .90 | 11.79 | .64 | .73 | .55 |
| Last rib | .76 | .78 | .81 | .75 | .73 | .77 | 9.15 | .61 | .40 | .57 |
| Last lumbar | .72 | .75 | .82 | .75 | .70 | .71 | 11.16 | .18 | .10 | .29 |
| Average[f] | .99 | 1.01 | 1.07 | 1.01 | .98 | 1.00 | 6.46 | .29 | .17 | .49 |
| LMA, $in^2$ | 5.27 | 5.20 | 4.97 | 5.01 | 5.30 | 5.37 | 7.97 | .14 | .11 | .24 |
| Lean %[g] | 49.88 | 49.24 | 48.73 | 49.66 | 49.98 | 50.54 | 4.05 | .62 | .51 | .79 |
| Dressing % | 72.07 | 72.24 | 71.22 | 72.09 | 72.75 | 71.30 | 1.63 | .42 | .24 | .34 |
| Visual color[h] | 2.42 | 2.38 | 2.71 | 2.46 | 2.58 | 2.33 | 12.64 | .53 | .66 | .50 |
| Firmness[h] | 2.63 | 2.63 | 3.21 | 2.75 | 2.58 | 2.63 | 19.10 | .25 | .19 | .58 |
| Marbling[h] | 2.71 | 2.67 | 3.13 | 2.92 | 2.75 | 2.63 | 17.75 | .20 | .19 | .57 |
| Hunter L*[i] | 52.75 | 53.42 | 50.33 | 51.96 | 53.60 | 53.66 | 5.55 | .18 | .12 | .34 |
| Hunter a*[i] | 11.48 | 11.28 | 11.59 | 12.41 | 12.47 | 11.86 | 12.85 | .41 | .68 | .94 |
| Hunter b*[i] | 7.73 | 7.88 | 7.16 | 8.14 | 8.53 | 8.18 | 19.36 | .93 | .67 | .67 |
| Hue angle[i] | 45.70 | 48.28 | 40.82 | 43.52 | 46.86 | 47.34 | 12.71 | .15 | .13 | .32 |
| Saturation index[i] | 13.86 | 13.77 | 13.63 | 14.87 | 15.12 | 14.43 | 14.56 | .62 | .92 | .84 |
| A:B ratio[i] | 1.52 | 1.44 | 1.63 | 1.59 | 1.47 | 1.48 | 8.72 | .10 | .07 | .13 |
| Drip loss, % | 3.33 | 3.92 | 2.25 | 2.85 | 4.49 | 3.73 | 61.56 | .28 | .17 | .19 |

[a]Values are means for two pigs/pen and six replications/treatment.
[b]Carcass length (mean = 31.74 in) and muscle score (mean = 2.51) were not affected (P>.20) by dietary treatment.
[c]Contrasts refer to the linear and quadratic comparisons of CrNic supplementation.
[d]Contrast refers to the comparison of supplementation with 200 ppb CrNic against that of 200 ppb CrPic.
[e]All contrasts between the control diets and diets containing 200 ppb CrPic were nonsignificant (P>.15).
[f]Average backfat is the average of the first and last rib and last lumbar fat depths.
[g]Lean percentage was derived from NPPC equations.
[h]Scoring system of 1 to 5: 2 = grayish pink, traces to slight, or soft and watery; 3 = reddish pink, small to modest, or slightly firm and moist; and 4 = purplish red, moderate to slightly abundant, or firm and moderately dry for color, firmness, and marbling, respectively.
[i]Means were derived from three sample readings per loin. Measures of dark to light (Hunter L*), redness (Hunter a*), yellowness (Hunter b*), red to orange (hue angle), or vividness or intensity (saturation index).

**Table 5. Carcass Characteristics of Gilts Fed Graded Levels of Chromium[a,b]**

| | CrNic | | | | | CrPic | | Probability | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | 0 | 50 | 100 | 200 | 400 | 200 | CV | Lin.[c] | Quad.[c] | Cont.[d] |
| Shrink loss, % | 2.20 | 2.45 | 2.28 | 2.25 | 2.39 | 2.40 | 16.61 | .96 | .88 | .54 |
| Backfat, in: | | | | | | | | | | |
| First rib | 1.40 | 1.46 | 1.49 | 1.52 | 1.46 | 1.50 | 6.61 | .03 | .04 | .27 |
| Tenth rib | .77 | .80 | .80 | .78 | .75 | .82 | 10.72 | .73 | .55 | .54 |
| Last rib | .69 | .71 | .73 | .69 | .69 | .69 | 10.48 | .96 | .87 | .88 |
| Last lumbar | .65 | .70 | .69 | .71 | .71 | .70 | 12.01 | .33 | .47 | .95 |
| Average[e] | .91 | .96 | .97 | .97 | .95 | .97 | 8.01 | .20 | .23 | .65 |
| LMA, $in^2$ | 5.93 | 5.70 | 6.04 | 5.78 | 6.09 | 5.59 | 8.10 | .74 | .57 | .26 |
| Lean %[f] | 53.46 | 52.40 | 52.84 | 52.60 | 54.05 | 51.60 | 3.27 | .35 | .21 | .16 |
| Dressing % | 72.02 | 72.04 | 72.66 | 73.09 | 72.24 | 72.81 | 1.20 | .02 | .02 | .10 |
| Visual color[g] | 2.50 | 2.63 | 2.46 | 2.42 | 2.63 | 2.58 | 6.86 | .15 | .09 | .05 |
| Firmness[g] | 2.92 | 3.04 | 2.96 | 2.75 | 2.75 | 2.79 | 12.10 | .52 | .81 | .99 |
| Marbling[g,h] | 2.88 | 2.46 | 2.79 | 2.46 | 2.46 | 2.58 | 11.65 | .17 | .37 | .99 |
| Hunter L*[i] | 51.18 | 50.65 | 51.90 | 51.02 | 52.05 | 49.85 | 4.32 | .99 | .82 | .43 |
| Hunter a*[i] | 11.41 | 10.87 | 10.06 | 11.04 | 11.84 | 10.86 | 9.91 | .14 | .06 | .21 |
| Hunter b*[i] | 7.47 | 6.91 | 6.86 | 7.17 | 7.69 | 6.81 | 13.46 | .32 | .18 | .36 |
| Hue angle[i] | 43.71 | 42.71 | 46.71 | 42.83 | 43.63 | 40.23 | 10.75 | .85 | .80 | .77 |
| Saturation index[i] | 14.00 | 12.89 | 12.19 | 13.19 | 14.13 | 12.41 | 9.96 | .10 | .05 | .22 |
| A:B ratio[i] | 1.55 | 1.58 | 1.49 | 1.62 | 1.56 | 1.69 | 9.22 | .72 | .75 | .47 |
| Drip loss, %[j] | 2.19 | 2.17 | 2.38 | 3.00 | 3.56 | 2.04 | 52.01 | .51 | .94 | .47 |

[a]Values are means for two pigs/pen and six replications/treatment. [b]Carcass length (mean = 32.15 in) and muscle score (mean = 2.53) were not affected (P>.20) by dietary treatment. [c]Contrasts refer to the linear and quadratic comparisons of CrNic supplementation. [d]Contrast refers to the comparison of supplementation with 200 ppb CrNic against that of 200 ppb CrPic. [e]Average backfat is the average of the first and last rib and last lumbar fat depths. [f]Lean percentage was derived from NPPC equations. [g]Scoring system of 1 to 5: 2 = grayish pink, traces to slight, or soft and watery; 3 = reddish pink, small to modest, or slightly firm and moist; and 4 = purplish red, moderate to slightly abundant, or firm and moderately dry for color, firmness, and marbling, respectively. [h]Control diet differs from diets containing 200 ppb CrPic (P = .02). [i]Means were derived from three sample readings per loin. Measures of dark to light (Hunter L*), redness (Hunter a*), yellowness (Hunter b*), red to orange (hue angle), or vividness or intensity (saturation index). [j]Control diets differ from diets containing 200 ppb CrPic (P = .08). All other contrasts between the control diets and diets containing 200 ppb CrPic were nonsignificant (P>.15).

**Table 6. Serum Chromium Levels of Pigs Fed Graded Levels of Chromium[a]**

| | CrNic | | | | | CrPic | | Probability | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | 0 | 50 | 100 | 200 | 400 | 200 | CV | Lin.[b] | Quad.[b] | Cont.[c] |
| Barrows: | | | | | | | | | | |
| Chromium[d,e] | 49.78 | 57.60 | 48.05 | 50.72 | 65.65 | 64.28 | 22.08 | .48 | .21 | .05 |
| Gilts: | | | | | | | | | | |
| Chromium[d] | 45.45 | 46.80 | 50.98 | 41.42 | 45.25 | 63.85 | 16.63 | .71 | .83 | .42 |

[a]Values represent the pooled results of two pigs/pen and six replications/treatment. All pigs were bled following a 3-h fast. [b]Contrasts refer to the linear and quadratic comparisons of CrNic supplementation. [c]Contrast refers to the comparison of supplementation with 200 ppb CrNic against that of 200 ppb CrPic. [d]Chromium values are expressed as nmol/L. [e]Control diets differ from diets containing 200 ppb CrPic (P = .03). All other contrasts between the control diets and diets containing 200 ppb CrPic were nonsignificant (P>.20).

# EFFECTS OF DIET MANIPULATION ON GROWTH PERFORMANCE, CARCASS CHARACTERISTICS, AND MEAT QUALITY OF INTACT MALE PIGS

*C. A. Maloney, R. H. Hines, J. D. Hancock, H. Cao, and J. S. Park*

## Summary

Castrates were predictably less efficient, had greater ADFI, and tended to have more BF than contemporary boars. Castration decreased detection of boar taint, but alterations of dietary CP, pH, and antimicrobial level from 225 to 276 lb had no effect on sensory panel perception of odor from fat of intact males.

(Key Words: Boars, Diet, Boar Odor.)

## Introduction

Use of intact males for fresh pork production in the United States offers many economically important advantages, such as improved feed efficiency and leaner carcasses when compared to barrows. Other advantages, which could lead to greater consumer acceptance of pork, are decreased animal welfare concerns (by ending surgical castration) and producing a leaner product with a high percentage of unsaturated fatty acids. However, the perception of off-odor or taint overshadows these advantages, with 35% of adults perceiving boar odor as objectionable. Skatole and androstenone are two unrelated compounds blamed for the undesirable odor during cooking and consumption of boar meat. The data reported herein result from an experiment designed to determine if diet manipulation affects taste panel perception of pork from intact males.

## Procedures

A total of 80 pigs (10 barrows and 70 boars with an average initial BW of 112 lb) was used in a 70-d growth assay to determine the effects of diet manipulation on growth performance, carcass characteristics, and meat quality of intact male pigs. The pigs were blocked by weight and allotted to pens based on gender and ancestry. There were two pigs per pen and five pens per treatment. The diets (Table 1) were formulated to 1.3% lysine, .75% Ca, and .65% P for 112 to 169 lb; 1.1% lysine, .65% Ca, and .55% P for 169 to 225 lb; and 1.1% lysine, .55% Ca, and .45% P for 225 to 276 lb. The pigs were fed the same diet to 225 lb BW. For 225 to 276 lb, barrows and a boar control received the basal diet. For the other treatments, dietary pH was decreased by adding citric acid (low pH) and increased with sodium bicarbonate (high pH), crude protein was increased by removing crystalline amino acids (low crystalline amino acids) and decreased by adding them (high crystalline amino acids), and antimicrobials were decreased by removing the tylosin from the diet (low antimicrobials) and increased by adding copper sulfate and tylosin to the diet (high antimicrobials).

The pigs were housed in an environmentally controlled finishing facility in 5-ft × 5-ft pens with totally slotted flooring. The pens were equipped with a single-hole self-feeder and nipple waterer to allow ad libitum consumption of feed and water. Pig and feeder weights were collected after each phase of the experiment to allow calculation of ADG, ADFI, and F/G. The pigs were killed at a commercial packing plant where HCW and BF were measured, and adipose samples were obtain for sensory analyses.

Consumer perception of the tissue samples was determined by a trained panel. All panel members were chosen from a pool of people subjected to a screening process, with the most sensitive to boar odor chosen for the

panel. The panel would not be considered a cross section of the population, because only those who were sensitive to boar taint were chosen. To determine level of boar taint, a small sample of fat was streaked across a hot plate, and the aroma immediately evaluated by each panelist. The samples were scored from 1 to 5 where: 1 = no odor; 2 = very slight; 3 = slight; 4 = moderate; and 5 = strong boar odor.

The experimental design was a randomized complete block with orthogonal contrasts used to separate treatment means. Comparisons were: barrows vs boars; control boars vs those with diet modifications; crystalline amino acids vs pH and antibiotics; low vs high crystalline amino acids; pH vs antibiotics; low vs high pH; and low vs high antibiotics.

## Results and Discussion

To 225 lb, ADG was not affected, but the barrows had greater ADFI ($P<.004$) and were less efficient ($P<.001$) than boars. From 225 to 276 lb, ADG and F/G were not affected by treatment ($P>.15$), although the barrows still had greater ADFI ($P<.02$) than the boars. Overall (from 112 to 276 lb) boars were 13% more efficient than barrows ($P<.002$) and consumed 8% less feed ($P<.009$).

From 225 to 276 lb, boars fed the low pH treatment consumed 21% less feed than the control boars and 14% less feed than boars fed the other treatments. This resulted in the boars fed low pH having lower ADFI ($P<.04$) than the boars fed high pH, although ADG and F/G were not affected ($P>.15$). Manipulating CP in the diet with crystalline amino acids did not affect growth performance, carcass measurements, or boar odor ($P<.12$). However, a trend ($P<.07$) for greater efficiency of gain occurred when pigs were fed the high antimicrobial treatment from 225 to 276 lb.

No differences occurred among the treatments for hot carcass weight or dressing percentage, but boars tended to be leaner ($P<.06$) than barrows. The barrows scored lower ($P<.002$) for odor than the boars, but diet manipulation did not affect ($P>.24$) odor among the boar treatments.

Based on the results of this experiment, castrates were less efficient, had increased ADFI, and tended to have greater BF than boars. Castration decreased boar taint, but alterations of dietary CP, pH, and antimicrobial concentrations, from 225 to 276 lb, did not affect sensory panel perception of odor from fat of intact males.

**Table 1. Diet Composition**

| | | | 225 to 276 lb[c] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Diet pH | | Crystalline amino acids | | Antimicrobials | |
| Item | 112 to 169 lb[a] | 169 to 225 lb[b] | Control | Low | High | Low | High | Low | High |
| Corn | 63.80 | 73.42 | 76.75 | 73.04 | 72.13 | 72.61 | 83.92 | 77.04 | 76.57 |
| Soybean meal (46.5% CP) | 30.49 | 21.19 | 18.95 | 19.58 | 19.73 | 23.37 | 10.81 | 18.90 | 18.98 |
| Soy oil | 2.00 | 2.00 | 1.23 | 2.70 | 3.06 | 1.29 | 1.30 | 1.12 | 1.30 |
| Monocalcium phosphate | 1.30 | .98 | .54 | .57 | .58 | .46 | .69 | .54 | .54 |
| Limestone | 1.08 | 1.03 | .99 | .97 | .97 | 1.00 | .97 | .99 | .99 |
| Salt | .35 | .35 | .35 | .35 | .35 | .35 | .35 | .35 | .35 |
| KSU vitamins and minerals | .40 | .40 | .40 | .40 | .40 | .40 | .40 | .40 | .40 |
| Citric acid | ---- | ---- | ---- | 1.60 | ---- | ---- | ---- | ---- | ---- |
| Sodium bicarbonate | ---- | ---- | ---- | ---- | 2.00 | ---- | ---- | ---- | ---- |
| Lysine-HCl | .28 | .35 | .43 | .42 | .41 | .27 | .72 | .43 | .43 |
| DL-methionine | .17 | .13 | .16 | .17 | .17 | .12 | .24 | .16 | .16 |
| L-threonine | ---- | .02 | .07 | .07 | .07 | | .19 | .07 | .07 |
| L-isoleucine | ---- | ---- | ---- | ---- | ---- | ---- | .14 | ---- | ---- |
| Valine | ---- | ---- | ---- | ---- | ---- | ---- | .10 | ---- | ---- |
| L-tryptophan | ---- | ---- | ---- | ---- | ---- | ---- | .04 | ---- | ---- |
| Antibiotic[d] | .13 | .13 | .13 | .13 | .13 | .13 | .13 | ---- | .13 |
| Copper sulfate[e] | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | .08 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

[a]Provided 1.3% lysine, .75% Ca, and .65% P.
[b]Provided 1.1% lysine, .65% Ca, and .55% P.
[c]Provided 1.1% lysine, .55% Ca, and .45% P.
[d]Provided 100 g/ ton tylosin.
[e]Provided 200 ppm total copper.

**Table 2. Effect of Diet Manipulation on Growth Performance and Carcass Characteristics[a]**

| | | | Diet pH | | Crystalline Amino Acids | | Antimicrobials | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | Barrows | Boars | Low | High | Low | High | Low | High | SE |
| 112 to 225 lb (d 0 to 46)[b] | | | | | | | | | |
| ADG, lb | 2.43 | 2.47 | ---- | ---- | ---- | ---- | ---- | ---- | .08 |
| ADFI, lb | 6.69 | 5.85 | ---- | ---- | ---- | ---- | ---- | ---- | .25 |
| F/G | 2.75 | 2.37 | ---- | ---- | ---- | ---- | ---- | ---- | .06 |
| 225 to 276 lb (d 46 to 70) | | | | | | | | | |
| ADG, lb | 2.10 | 2.37 | 1.95 | 2.12 | 2.09 | 2.32 | 1.90 | 2.13 | .16 |
| ADFI, lb | 7.77 | 7.64 | 6.05 | 6.92 | 7.07 | 7.49 | 6.81 | 6.69 | .28 |
| F/G | 3.70 | 2.83 | 3.10 | 3.26 | 3.38 | 3.23 | 3.58 | 3.14 | .23 |
| 112 to 276 lb (d 0 to 70) | | | | | | | | | |
| ADG, lb | 2.31 | 2.45 | 2.17 | 2.39 | 2.41 | 2.42 | 2.25 | 2.35 | .08 |
| ADFI, lb | 7.08 | 6.49 | 5.88 | 6.43 | 5.83 | 6.42 | 6.14 | 6.06 | .30 |
| F/G | 3.06 | 2.65 | 2.71 | 2.69 | 2.42 | 2.65 | 2.73 | 2.58 | .11 |
| HCW, lb | 204 | 205 | 204 | 207 | 208 | 205 | 204 | 206 | 2.7 |
| DP, %[c] | 74.2 | 74.4 | 74.0 | 75.0 | 75.4 | 74.3 | 74.0 | 75.9 | 1.0 |
| BF, in[d] | 1.02 | .98 | .94 | .94 | .91 | .91 | .87 | .91 | .15 |
| Odor[e] | 2.2 | 2.8 | 3.0 | 3.1 | 3.3 | 3.0 | 2.9 | 3.2 | .2 |

[a]Eighty pigs (10 barrows and 70 boars initially 112 lb) with 2 pigs/pen and 5 pens/trt.
[b]Manipulation of the diets was not initiated until d 46 (225 lb BW).
[c]Calculated as HCW / live weight x 100.
[d]Last rib (midline) fat depth.
[e]Values result from analyses by a trained sensory panel (1 = none; 2 = very slight; 3 = slight; 4 = moderate; and 5 = strong).

**Table 3. Probability values (P <)**

| Item | Barrows vs Others | Control Boars vs Diet Manipulations | Amino Acids vs pH And Antimicrobials | Low vs High Amino Acids | pH vs Anti-microbials | Low vs High pH | Low vs High Antimicrobials |
|---|---|---|---|---|---|---|---|
| 112 to 225 lb (d 0 to 46)[a] | | | | | | | |
| ADG, lb | ----[b] | ---- | ---- | ---- | ---- | ---- | ---- |
| ADFI, lb | .004 | ---- | ---- | ---- | ---- | ---- | ---- |
| F/G | .001 | ---- | ---- | ---- | ---- | ---- | ---- |
| 225 to 276 lb (d 46 to 70) | | | | | | | |
| ADG, lb | ---- | .12 | ---- | ---- | ---- | ---- | ---- |
| ADFI, lb | .02 | .02 | .02 | ---- | ---- | .04 | ---- |
| F/G | ---- | ---- | ---- | ---- | ---- | ---- | .07 |
| 112 to 276 lb (d 0 to 70) | | | | | | | |
| ADG, lb | ---- | ---- | .08 | ---- | ---- | .07 | ---- |
| ADFI, lb | .009 | ---- | ---- | ---- | ---- | ---- | ---- |
| F/G | .002 | ---- | .12 | .12 | ---- | ---- | ---- |
| HCW, lb | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| DP, % | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| BF, cm | .06 | ---- | ---- | ---- | ---- | ---- | ---- |
| Odor | .002 | ---- | ---- | ---- | ---- | ---- | ---- |

[a]Manipulation of the diets was not initiated until d 46 (225 lb BW).
[b]Dash indicates (P>.15).

*Swine Day 1998*

# ENZYME ADDITIONS TO SORGHUM-BASED DIETS FOR FINISHING PIGS [1]

*J. S. Park, J. D. Hancock, R. H. Hines, C. A. Maloney*
*J. M. DeRouchey, H. Cao, and D. J. Lee*

## Summary

Three experiments were conducted to determine the effects of a sorghum-specific enzyme supplementation on growth performance of finishing pigs. Although positive trends occurred, the sorghum-specific enzymes used in our experiments did not yield large and(or) consistent improvements in growth performance or nutrient digestibility in finishing pigs.

(Key Words: Sorghum, Enzyme, Finishing Pigs.)

## Introduction

The hardy nature of sorghum makes it appealing to farmers and livestock producers in the High Plains of the U.S., throughout Mexico, and in relatively arid regions in the most of world. Yet the feeding value of sorghum grain on average is 3 to 5% less than that of corn. Thus, a means of improving nutrient utilization from sorghum grain would be of great benefit. Some researchers have suggested that enzyme supplementation of swine and poultry diets (e.g., beta glucanase in barley-based diets and phytase in most cereal-based diets) can improve nutrient utilization and(or) growth performance. Thus, the objective of this experiment was to determine the effects of sorghum-specific enzyme supplementation on growth performance and nutrient utilization in finishing pigs.

## Procedures

For Exp. 1, 192 pigs (PIC line 326 boars × C15 and C22 sows) were blocked by weight (average initial BW of 100 lb) and allotted to pen based on sex and ancestry. There were 12 gilts in eight pens and 12 barrows in eight pens. Treatments were the sorghum-soybean meal-based diets with none and 12 oz of enzyme derived from *A. niger* and *B. subtilis* fermentation extract (carbohydrase; 50.000 BA unit/oz + cellu-lase; 100 F unit/oz.) per ton of sorghum. Water was added with the enzyme system so that all diets had 12 oz of supplemental liquid. The enzyme system and(or) water were mixed with the sorghum for 5 min before other dietary ingredients were added to the mixer. The pigs were housed in a modified open-front building with 50% solid concrete and 50% concrete slat flooring. Each pen (6 ft × 16 ft) had a three-hole self-feeder and nipple waterer to allow ad libitum consumption of feed and water.

At approximately midexperiment (d 39), chromic oxide (.25%) was added to the diets as an indigestible marker. After a 4-d adjustment period, fecal samples were collected from four pigs per pen, pooled within pen, and frozen. Later, the feces were oven-dried at 122°F for 24 hr and ground. Feed and feces were analyzed for concentrations of DM, N, and Cr to allow calculation of apparent digestibilities of DM and N.

The pigs were slaughtered when those in the heaviest pen in a weight block reached an

[1]Appreciation is expressed to Charles Cobb of Loveland Industries, Inc., for funding this project.

average BW of 250 lb. Dressing percentage (hot carcass weight / final live weight × 100) and tenth rib backfat thickness (measured on the midline of the split carcass) for each pig were adjusted (using regression analysis) to the average final BW before being pooled within pen. Also, fat-free lean index for each pen was calculated using the equation proposed by the National Pork Producers Council (1994). Response criteria were ADG, ADFI, F/G, dressing percentage, last rib backfat thickness, fat-free lean index, and apparent digestibilities of DM and N. All data were analyzed as a randomized complete block design (with BW as the blocking criterion) using the GLM procedures of SAS.

For Exp. 2, 168 pigs (same genetics as for Exp. 1 with an average initial BW of 129 lb) were blocked by weight and allotted to pen based on sex and ancestry. There were 11 gilts in eight pens and 10 barrows in eight pens. Pig and feeder management and housing were the same as in Exp.1.

Treatments were a sorghum-soybean meal-based diet with no enzyme or 5, 10, and 15 oz of the enzyme supplementation added to each ton of sorghum. Water was added with the enzyme system so that all diets had 15 oz of supplemental liquid. The diets (Table 1) were formulated to .90% lysine for d 0 to 29 and .70 % lysine for d 29 to 63 and fed in meal form. Fecal sample collection, preparation, and analyses were the same as in Exp. 1. All data were analyzed as a randomized complete block design using the GLM procedures of SAS. Polynomial regression was used to characterize the shape of the response curve, and pen was the experimental unit. Response criteria were the same as in Exp. 1 (e.g., growth performance, nutrient digestibility, and routine carcass measurements).

For Exp. 3, 176 pigs (same genetics as for Exp. 1 with average initial BW of 103 lb) were blocked by weight and allotted to pen based on sex and ancestry. There were 11 gilts in eight pens and 11 barrows in eight pens. Treatments were the same sorghum-soybean meal-based diets used in Exps. 1 and 2, with no enzyme or 15, 30, and 40 oz of enzyme supplementation per ton of sorghum. Pig and feeder managements were the same as in the previous experiments. Collecting of carcass data was slightly different (i.e., a different slaughter plant), with fat thickness measured off-midline, at the tenth rib, using a Fat-O-Meter probe. Also hot carcass weights were "head on". Response criteria and data analyses were the same as in Exp. 2.

**Table 1. Basal Diets[a]**

| Ingredient, % | Period 1[b] | Period 2[c] |
|---|---|---|
| Sorghum | 82.57 | 90.00 |
| Soybean meal (46.5% CP) | 13.40 | 6.52 |
| Soybean oil | .50 | .50 |
| Lysine HCL | .39 | .38 |
| Threonine | .18 | .15 |
| DL-methionine | .17 | .14 |
| Monocalcium phosphate | 1.10 | 1.00 |
| Limestone | 1.02 | .73 |
| Salt | .30 | .30 |
| Vitamin premix | .15 | .15 |
| Trace mineral premix | .10 | .10 |
| Antibiotic[d] | .12 | .12 |
| Total | 100.00 | 100.00 |

[a]All diets were fed in mash form.
[b]Formulated to .90% lysine, .65% Ca, and .55% P, and fed from d 0 to 29, d 0 to 35, and d 0 to 39 in Exp.1, 2, and 3, respectively.
[c]Formulated to .70% lysine, .55% Ca, and .45% P, and fed from d 29 to 63, d 35 to 71, and d 39 to 74 in Exp.1, 2, and 3, respectively.
[d]Supplied 100g/ton tylosin.

## Results and Discussion

For Exp. 1, F/G for d 0 to 39 was improved (P<.03) by enzyme supplementation. However, other measurements of growth performance were not affected (P>.15) for d 0 to 39, d 39 to 74, or overall. Digestibility of DM tended (P<.13) to be greater in pigs fed diet with enzymes, but digestibility of N was not affected (P>.15). Pigs fed the diet with enzymes had greater dressing percentage (P<.03), but BF and FFLI were not affected (P>.24).

For Exp. 2, adding as much as 15 oz/ton of the enzyme supplementation did not affect

(P>.15) ADG, ADFI, or F/G for d 0 to 29. During d 29 to 63, the linear effect of enzyme concentration on F/G approached significance (P<.11), with an 8.5% advance as enzyme concentration was increased from none to 15 oz/ton of sorghum. However, for the overall period (d 0 to 63), growth performance; digestibilities of DM and N; and carcass characteristics (dressing percentage, backfat thickness, and fat-free lean index) were not affected (P>.15) by addition of the enzyme system.

For Exp. 3, enzyme supplementation had no effect on ADG, ADFI, F/G, or digestibilities of DM and N (d 39), and carcass characteristics (dressing percentage, backfat thickness, and fat free lean index) were similar among treatments (P>.15) when up to 45 oz/ton of enzyme was added.

In conclusion, positive trends occurred, but enzyme supplementation to sorghum-based diets showed no consistent advantages. Still, the feeding value of sorghum is less than that of corn, so the search for a cost-effective enzyme supplement will continue.

**Table 2. Effects of Sorghum-Specific Enzyme on Growth Performance of Finishing Pigs (Exp.1)[a]**

| | Enzyme Concentration, oz/ton of Sorghum | | | |
|---|---|---|---|---|
| Item | 0 | 12 | SE | P- value |
| Day 0 to 39 | | | | |
| ADG, lb | 2.12 | 2.16 | .05 | -[c] |
| ADFI, lb | 4.87 | 4.79 | .13 | - |
| F/G | 2.29 | 2.21 | .03 | .03 |
| Day 39 to 74 | | | | |
| ADG, lb | 1.90 | 1.94 | .06 | - |
| ADFI, lb | 5.66 | 5.96 | .17 | - |
| F/G | 2.98 | 3.07 | .07 | - |
| Overall | | | | |
| ADG, lb | 2.01 | 2.05 | .05 | - |
| ADFI, lb | 5.44 | 5.50 | .19 | - |
| F/G | 2.70 | 2.68 | .05 | - |
| Nutrient digestibility (d 43), % | | | | |
| DM | 84.4 | 85.4 | .9 | .13 |
| N | 66.0 | 67.1 | 1.9 | - |
| Carcass measurements [b] | | | | |
| DP, % | 72.3 | 73.1 | .4 | .03 |
| BF, in | .89 | 1.02 | .14 | - |
| FFLI, % | 47.2 | 45.4 | 2.1 | - |

[a]A total of 192 finishing pigs was fed from an average initial BW of 100 lb to an average final BW of 248 lb.
[b]DP = dressing percentage, BF = tenth rib backfat thickness, and FFLI = fat free lean index (NPPC, 1994).
[c]Dash indicates P>.15.

**Table 3. Effects of Sorghum-Specific Enzyme on Growth Performance of Finishing Pigs (Exp.2)[a]**

| | Enzyme Concentration, oz/ton of Sorghum | | | | | P-Value | | |
|---|---|---|---|---|---|---|---|---|
| Item | 0 | 5 | 10 | 15 | SE | Lin | Quad | Cubic |
| Day 0 to 29 | | | | | | | | |
| ADG, lb | 2.15 | 2.16 | 2.13 | 2.14 | .09 | -[c] | - | - |
| ADFI, lb | 4.70 | 4.80 | 4.73 | 4.65 | .12 | - | - | - |
| F/G | 2.19 | 2.22 | 2.22 | 2.17 | .02 | - | - | - |
| Day 29 to 63 | | | | | | | | |
| ADG, lb | 1.87 | 2.00 | 1.98 | 2.08 | .10 | - | - | - |
| ADFI, lb | 5.90 | 6.09 | 6.00 | 6.00 | .23 | - | - | - |
| F/G | 3.16 | 3.05 | 3.03 | 2.88 | .01 | .11 | - | - |
| Overall | | | | | | | | |
| ADG, lb | 1.99 | 2.08 | 2.05 | 2.11 | .09 | - | - | - |
| ADFI, lb | 5.55 | 5.68 | 5.59 | 5.56 | .22 | - | - | - |
| F/G | 2.79 | 2.73 | 2.73 | 2.64 | .01 | - | - | - |
| Nutrient digestibility (d32),% | | | | | | | | |
| DM | 83.4 | 84.5 | 84.0 | 84.7 | .7 | - | - | - |
| N | 62.4 | 62.7 | 61.6 | 63.3 | .1 | - | - | - |
| Carcass measurements [b] | | | | | | | | |
| DP, % | 72.6 | 74.5 | 72.9 | 73.1 | .7 | - | - | - |
| BF, in | 1.00 | .97 | 1.00 | .99 | .02 | - | - | - |
| FFLI, % | 45.6 | 46.3 | 45.8 | 46.0 | .4 | - | - | - |

[a]A total of 168 finishing pigs was fed from an average initial BW of 129 lb to an average final BW of 256 lb. [b]DP = dressing percentage, BF = tenth rib backfat thickness, and FFLI = fat free lean index (NPPC, 1994). [c]Dash indicates P>.15.

**Table 4. Effects of Sorghum-Specific Enzyme on Growth Performance of Finishing Pigs (Exp.3)[a]**

| | Enzyme Concentration, oz/ton of Sorghum | | | | | P-Value | | |
|---|---|---|---|---|---|---|---|---|
| Item | 0 | 15 | 30 | 45 | SE | Lin | Quad | Cubic |
| Day 0 to 36 | | | | | | | | |
| ADG, lb | 2.12 | 2.08 | 2.10 | 2.15 | .09 | -[c] | - | - |
| ADFI, lb | 5.60 | 5.40 | 5.48 | 5.54 | .21 | - | - | - |
| F/G | 2.64 | 2.59 | 2.60 | 2.58 | .13 | - | - | - |
| Day 36 to 71 | | | | | | | | |
| ADG, lb | 2.10 | 2.09 | 2.11 | 2.06 | .11 | - | - | - |
| ADFI, lb | 6.99 | 6.95 | 6.94 | 6.87 | .26 | - | - | - |
| F/G | 3.32 | 3.33 | 3.28 | 3.33 | .13 | - | - | - |
| Overall | | | | | | | | |
| ADG, lb | 2.10 | 2.09 | 2.11 | 2.11 | .07 | - | - | - |
| ADFI, lb | 6.55 | 6.47 | 6.44 | 6.51 | .18 | - | - | - |
| F/G | 3.11 | 3.09 | 3.05 | 3.08 | .10 | - | - | - |
| Nutrient digestibility (d39), % | | | | | | | | |
| DM | 83.6 | 83.7 | 83.8 | 84.2 | .4 | - | - | - |
| N | 62.7 | 64.4 | 63.7 | 64.2 | 1.1 | - | - | - |
| Carcass measurements [b] | | | | | | | | |
| DP, % | 76.5 | 76.1 | 74.3 | 76.5 | 2.4 | - | - | - |
| BF, in | .72 | .71 | .69 | .70 | .04 | - | - | - |
| FFLI, % | 49.4 | 49.5 | 49.7 | 49.7 | .5 | - | - | - |

[a]A total of 176 finishing pigs was fed from an average initial BW of 103 lb to an average final BW of 252 lb. [b]DP = dressing percentage (head-on), BF = tenth rib backfat thickness, and FFLI = fat free lean index (NPPC, 1994). [c]Dash indicates P>.15.

*Swine Day 1998*

# ADDED DIETARY FAT IMPROVES GROWTH PERFORMANCE AND FEED EFFICIENCY IN GROWING-FINISHING PIGS UNDER COMMERCIAL CONDITIONS

*M. D. Tokach [1], S. S. Dritz [2], R. D. Goodband, and J. L. Nelssen*

## Summary

A total of 480 pigs was used in an experiment conducted in a commercial research facility to determine the influence of fat additions to the growing-finishing diet on pig performance and carcass composition. Adding fat to the diet from 80 to 265 lb increased ADG and F/G by 1 and 2%, respectively, for each 1% added fat. The growth response was greatest during the initial phase of the trial (80 to 130 lb) and declined as the trial progressed. The feed efficiency response was consistent throughout the trial. After adjusting for the greater carcass weight of pigs consuming the high fat diets, carcass parameters were not influenced by fat addition to the diet.

(Key Words: Dietary Fat, Growing-Finishing Pig, Growth.)

## Introduction

Several experiments have been conducted to determine the influence of fat additions to growing-finishing diets on pig performance and carcass composition. In general, average daily gain is expected to increase 1% for every percent added fat, and feed efficiency is expected to improve 2% for every percent added fat. However, several questions arise with this simplistic rule of thumb. First, is the response to added fat the same at all levels of addition (i.e., is the response from increasing dietary fat from 0 to 2% the same as increasing fat from 4 to 6%)? Second, is the response the same for all phases during growing-finishing? Because pigs are more energy deficient in the early finisher period, we would expect a greater response during this period; however, this actual level of response is not well characterized. Third, recent trials in university research settings demonstrate a much smaller response to fat additions to grain-soybean meal diets than those in the rule of thumb presented above. The reason is probably the fact that feed intake is normally 25 to 40% higher in university research settings than under field conditions. Therefore, the objective of this research was to determine the influence of graded levels of added fat on carcass composition and growth performance of growing-finishing pigs in a research facility closely approximating field conditions.

## Procedures

The experiment was conducted in a commercial research unit holding 24 pens with 20 pigs per pen. Pigs (PIC) were allotted randomly to pens each having an initial average pig weight of 80 lb. There were 12 pens of barrows and 12 pens of gilts (3 pens of each sex per treatment). Pens had totally slatted floors and were 8 ft by 18 ft to provide 7.2 sq ft per pig. Pens were equipped with a cup waterer and 4-hole feeder.

The four dietary treatments were based on level of added dietary fat (0, 2, 4, or 6%). Diets were fed in three phases with the lysine:calorie ratio decreasing with each phase. The dietary phases and corresponding lysine:ME ratios and lysine levels are shown

[1]Northeast Area Extension Office, Manhattan, KS.
[2]Food Animal Health and Management Center.

in Table 2. Diets were switched by sex, with all pens within a sex being switched on the same day. Diets were switched when the average pen weight for all pigs of that sex reached 130 and 205 lb. All diets were formulated to a constant lysine to energy ratio within phase. All diets were corn-soybean meal based with similar levels of vitamins, and minerals. Lysine levels were altered in the diets by adjusting the corn-soybean meal ratio. The diets did not contain any synthetic amino acids. Tylan was fed at 40 g/ton during phase 1, 20 g/ton during phase 2, and 10 g/ton during phase 3.

All pens were weighed on a weekly basis to determine average daily gain. Feed delivery was recorded daily, and feed remaining in the feeders weighed weekly to determine feed intake and feed efficiency.

Pigs were marketed by treatment to obtain carcass data. Three pigs per pen were marketed 3 weeks prior to the final marketing of the whole barn, with each treatment on a separate close out. Pens were weighed just prior to and just after marketing the three pigs per pen. Feed intake also was recorded to that point to ensure proper data collection. Data were analyzed for linear and quadratic effects, with pen serving as the experimental unit for all data analysis. Because no treatment × sex interactions occurred, data were pooled for analysis.

**Table 1. Lysine to Calorie Ratio (g lys/Mcal ME) and Lysine Level for Each Diet**

| | | | Added Dietary Fat, % | | | |
|---|---|---|---|---|---|---|
| Phase | Weight | Lysine: ME | 0 | 2 | 4 | 6 |
| 1 | 80 to 130 | 3.67 | 1.21 | 1.24 | 1.27 | 1.30 |
| 2 | 130 to 205 | 2.67 | .875 | .90 | .925 | .95 |
| 3 | 205 to market | 1.97 | .655 | .67 | .685 | .70 |

## Results and Discussion

During phase 1 (80 to 130 lb), ADG and F/G improved linearly (P<.05) as dietary fat increased from 0 to 6% (Table 2). Average daily feed intake was not influenced by fat additions. During phase 2 (130 to 210 lb), the response in ADG was not as great (linear, P<.13); however, the response in F/G (linear, P<.05) was similar. During phase 3 (210 to 265 lb), ADFI and F/G decreased linearly (P<.05) as fat was added to the diet. Added dietary fat did not influence ADG. For the overall period, ADG and F/G improved linearly (P<.05) as additional fat was added to the diet. A trend for lower ADFI (P<.13) also occurred as dietary fat increased.

Carcass data were analyzed without and with adjustment for a common carcass weight (Table 3). When the data were not adjusted for the increased weight gain for pigs fed the diets with added fat, carcass weight, backfat, and sort loss increased linearly (P<.05). Lean percentage and premium per pig decreased linearly (P<.05) with increasing dietary fat. After the data were adjusted to a common market weigh, no differences occurred in any of the carcass or sale price parameters. These data demonstrate the importance of adjusting the data to a common market weight to demonstrate the true treatment effects. Under the circumstances of this trial, fat level of up to 6% can be added to corn-soybean meal-based diets for growing-finishing pigs without negatively influencing standard carcass parameters or premiums received.

For a more complete understanding of the change in growth response from one phase to the next, the influence of added fat on pig performance is listed as the percentage improvement over the control diet in Table 4. The influence of fat level on ADG was greater (1.5% for every 1% fat) and more consistent during phase 1 than during subsequent phases. Overall, addition of each 1% fat resulted in approximately a 1% increase in

ADG. The negative influence of added fat on ADFI became greater as the trial progressed, with approximately 1% reduction in ADFI for every 1% added fat. The most consistent response to dietary fat was the improvement in F/G. Every 1% addition of fat resulted in approximately 2% improvement in F/G, and the response was consistent for each further addition of fat to the diet.

Using the economic scenario presented in Table 2, adding fat to the diet will not consistently reduce feed cost per pound of gain. Any economic calculations, however, also must include the impact of the improvement in ADG. The value of the extra gain will depend on the availability of growing-finishing space. For systems that have excess space or can easily contract additional space, the advantage in ADG is worth only the reduced number of days in the facility. For example, adding 6% fat to the diet during phases 1 and 2 reduces the number of days needed to grow from 80 to 210 lb from 78 to 73 d. If the space is worth only $.10/day, the extra gain is worth only $.50 per pig. For systems with limited space (i.e., systems with difficulty reaching the desired market weight), the advantage in ADG is worth the extra pounds sold at market. In this example, adding 6% fat to the diet during phases 1 and 2 increases the weight per pig by 8.6 lb (130 vs. 138.6 lb gain) with the same number of days. If market price was $40/cwt, the extra weight would be worth an additional $3.44. Therefore, the economics of whether fat should be added to the growing-finishing diet depend on the design of the production system as well as the prices of corn, soybean meal, and fat. These results demonstrated that pigs in this production system were energy deficient during phases 1 and 2, leading to the large growth response.

**Table 2. Influence of Level of Added Dietary Fat on Pig Performance and Feed**

| | Added Dietary Fat, % | | | | |
|---|---|---|---|---|---|
| Item | 0 | 2 | 4 | 6 | CV |
| Phase 1 (80 to 130 lb) | | | | | |
| ADG, lb[a] | 1.79 | 1.83 | 1.89 | 1.97 | 4.5 |
| ADFI, lb | 4.12 | 4.02 | 4.00 | 3.99 | 6.9 |
| F/G[a] | 2.30 | 2.20 | 2.12 | 2.02 | 4.6 |
| Feed cost, $/lb[c] | .164 | .164 | .165 | .163 | |
| Phase 2 (130 to 210 lb) | | | | | |
| ADG, lb[b] | 1.59 | 1.58 | 1.67 | 1.67 | 6.6 |
| ADFI, lb | 4.83 | 4.68 | 4.71 | 4.56 | 8.5 |
| F/G[a] | 3.04 | 2.97 | 2.81 | 2.72 | 4.6 |
| Feed cost, $/lb[c] | .207 | .211 | .209 | .210 | |
| Phase 3 (210 to 265 lb) | | | | | |
| ADG, lb | 1.54 | 1.54 | 1.62 | 1.58 | 6.1 |
| ADFI, lb[a] | 5.64 | 5.45 | 5.49 | 5.15 | 5.9 |
| F/G[a] | 3.67 | 3.53 | 3.38 | 3.25 | 4.4 |
| Feed cost, $/lb[c] | .217 | .220 | .222 | .224 | |
| Overall | | | | | |
| ADG, lb[a] | 1.63 | 1.63 | 1.72 | 1.72 | 4.0 |
| ADFI, lb[b] | 4.87 | 4.72 | 4.75 | 4.58 | 6.3 |
| F/G[a] | 2.99 | 2.88 | 2.76 | 2.65 | 3.7 |

[a]Linear effect of added fat (P<.05).
[b]Linear effect of added fat (P< .13).
[c]Prices used to figure cost per lb of gain include $2.50/bu corn, $200/ton SBM, and $.19/lb fat.

**Table 3. Influence of Level of Added Dietary Fat on Carcass Parameters and Market Price**

| | Added Dietary Fat, % | | | | |
|---|---|---|---|---|---|
| Item | 0 | 2 | 4 | 6 | CV |
| Backfat, in[a] | .66 | .72 | .67 | .75 | 7.1 |
| Loin depth, in | 2.26 | 2.31 | 2.30 | 2.29 | 3.1 |
| Lean, %[a] | 55.5 | 54.7 | 55.5 | 54.2 | 1.3 |
| Yield, % | 76.3 | 76.6 | 76.3 | 76.7 | .9 |
| Carcass weight, lb[a] | 189.9 | 194.8 | 200.1 | 201.0 | 4.1 |
| Live weight, lb[a] | 248.8 | 254.3 | 262.0 | 262.3 | 3.9 |
| Price info | | | | | |
| Live price, $/cwt | 58.20 | 57.03 | 56.66 | 57.01 | 4.3 |
| Premium, $/cwt[a] | 4.54 | 3.91 | 4.45 | 3.70 | 11.2 |
| Sort, $/cwt[a] | .18 | .40 | .70 | .75 | 75 |
| Adjusted to common carcass weight (196.6 lb)[b] | | | | | |
| Backfat, in | .68 | .73 | .65 | .73 | 5.8 |
| Loin depth, in | 2.29 | 2.32 | 2.29 | 2.27 | 2.7 |
| Lean, % | 55.2 | 54.6 | 55.6 | 54.5 | 1.2 |
| Yield, % | 76.5 | 76.7 | 76.2 | 76.5 | .9 |
| Price info | | | | | |
| Live price, $/cwt | 56.84 | 56.70 | 57.37 | 57.94 | 3.2 |
| Premium, $/cwt | 4.38 | 3.87 | 4.54 | 3.81 | 10.4 |
| Sort, $/cwt | .39 | .45 | .59 | .61 | 56.4 |

[a]Linear effect of dietary fat (P<.05)
[b]No Significant differences when adjusted to a common carcass weight.

**Table 4. Influence of Added Dietary Fat on Percentage Response in Pig Performance**

| | Added Dietary Fat, % | | | | Response per |
|---|---|---|---|---|---|
| Item | 0 | 2 | 4 | 6 | 1% Fat |
| Average daily gain | | | | | |
| Phase 1 (80 to 130 lb) | 0 | 2.2% | 5.5% | 10.1% | 1.5% |
| Phase 2 (130 to 210 lb) | 0 | -0.9% | 5.2% | 4.9% | 0.8% |
| Phase 3 (210 to 265 lb) | 0 | 0.4% | 5.5% | 2.7% | 0.6% |
| Overall | 0 | 0.4% | 5.3% | 5.7% | 0.83% |
| Average daily feed intake | | | | | |
| Phase 1 (80 to 130 lb) | 0 | -2.2% | -2.7% | -3.1% | -0.8% |
| Phase 2 (130 to 210 lb) | 0 | -3.2% | -2.4% | -5.8% | -1.1% |
| Phase 3 (210 to 265 lb) | 0 | -3.4% | -2.8% | -8.7% | -1.3% |
| Overall | 0 | -3.1% | -2.5% | -6.1% | -1.1% |
| Feed efficiency | | | | | |
| Phase 1 (80 to 130 lb) | 0 | -4.3% | -7.8% | -12.0% | -2.0% |
| Phase 2 (130 to 210 lb) | 0 | -2.5% | -7.5% | -10.5% | -1.6% |
| Phase 3 (210 to 265 lb) | 0 | -3.7% | -7.9% | -11.2% | -1.9% |
| Overall | 0 | -3.5% | -7.6% | -11.3% | -1.84% |

*Swine Day 1998*

# EFFECTS OF POULTRY FAT AND CHOICE WHITE GREASE ON PORK LONGISSIMUS MUSCLE, BELLY, AND BACON QUALITY [1]

***J. J. Engel, J. W. Smith, II, R. D. Goodband, J. A. Unruh, M. D. Tokach [2], and J. L. Nelssen***

## Summary

Eighty-four crossbred gilts were used to examine the effects of increasing dietary additions of poultry fat (PF) or choice white grease (CWG) on longissimus muscle (LM), belly, and bacon quality. Pigs fed PF had greater LM cooking loss values than those fed CWG. As PF increased in the diet, LM Minolta L* and belly lean values decreased, then increased. Neither fat source nor level significantly affected other LM quality or sensory traits. As PF increased, bacon-slicing score decreased. Although all taste panel scores were well within acceptable ranges, bacon from pigs fed PF had higher sensory panel "off flavor" scores than bacon from those fed CWG. These data indicate that PF and CWG can be added to finishing pig diets with minimal affects on LM, belly, and bacon quality.

(Key Words: Pork, Dietary Fat, Longissimus Muscle Quality.)

## Introduction

Much research has been conducted to investigate the effects of dietary fat additions on finishing pig growth performance and carcass characteristics. Research from Kansas State University has indicated that increasing choice white grease (CWG) up to 6% of the diet did not affect growth performance or standard carcass characteristics of finishing pigs. However, the effects of alternative energy sources on longissimus muscle (LM), belly, and bacon quality of finishing pigs has not been examined. We know that differences in saturated and unsaturated fat depositions in pork carcasses can result from the source of dietary fat added to the finishing pig diet. Adding poultry fat (PF), a relatively unsaturated fat source, at high levels might have an negative influence on pork quality.

Therefore, the objective of this study was to compare the effects of increasing dietary PF or CWG on pork LM, belly, and bacon quality.

## Procedures

Eighty-four crossbred gilts, (PIC L326 × C15, initially 133 lb) were used in this experiment. Choice white grease and PF were added at 2, 4, or 6% to a corn-soybean meal-based control diet (Table 1). Pigs were blocked by ancestry and allotted to one of seven dietary treatments.

The experimental control diet did not contain any added fat and was formulated to .75% lysine, .55% Ca, .50% P, and 2.26 g lysine/ Mcal ME. This lysine-calorie ratio was maintained in all of the diets containing PF or CWG and varied from .75 to .81%. The corn-soybean meal-based experimental diets were fed ad libitum in a meal form. The pigs were housed in an environmentally controlled finishing barn with 4 ft × 4 ft totally slatted pens. Each treatment included a pen with two pigs and six replicate pens.

[1]The authors thank the U.S. Poultry & Egg Association for partial financial support.
[2]Northeast Area Extension Office, Manhattan, KS.

Individual fat sources were analyzed for their fatty acid profiles (Table 2). These profiles indicated that the percentages of palmitic fatty acids were very similar between the two fat sources. Palmitoleic and linoleic acid levels were almost double in PF as compared to CWG. Stearic acid levels were nearly double in CWG. Oleic acid levels were slightly higher in CWG than in PF.

**Table 1. Basal Diet Composition[a]**

| Item | % |
|---|---|
| Corn | 83.33 |
| Soybean meal, 46.5% | 14.07 |
| Monocalcium phosphate | 1.01 |
| Limestone | .83 |
| Salt | .35 |
| L-Lysine HCl | .15 |
| Vitamin premix | .15 |
| Trace mineral premix | .10 |
| Ethoxyquin | .01 |
| Choice white grease[b] | - - |
| Poultry fat[b] | - - |
| Total | 100.00 |

[a]Diets were formulated to 2.26 g lysine/Mcal ME, .60% Ca, and .50% P. Dietary lysine levels ranged from .75 to .81%.
[b]Choice white grease and poultry fat were added at 2, 4, or 6% to provide the experimental diets.

Both fat sources were analyzed using several key quality indicators (Table 3). Choice white grease tended to have a higher peroxide value. Nonetheless, this analysis revealed that both fat sources were of high quality.

Pigs were slaughtered at the Kansas State University Meats Laboratory when the mean weight of pigs in a pen reached 240 lb. At 24 hours postmortem, standard carcass measurements were taken. The carcasses were ribbed at the tenth rib and allowed to bloom for 30 minutes. At this time, the LM was evaluated by a three-person panel for visual quality characteristics including marbling, color, and firmness and wetness. Longissimus color was evaluated on a 1 to 5 scale with 1 representing a muscle that was pale-pinkish-gray, and 5 being a muscle that was dark-purplish red. Longissimus visual firmness and wetness were evaluated on a 1 to 5 scale, with 1 being very soft and watery and 5 being very firm and dry. Visual marbling was evaluated on a 1 to 5 scale, with 1 being practically devoid and 5 being moderately abundant or greater.

**Table 2. Fatty Acid Profiles of Choice White Grease and Poultry Fat**

| Fatty Acid, % | PF | CWG |
|---|---|---|
| Palmitic (16:0) | 22.2 | 23.3 |
| Palmitoleic (16:1) | 8.4 | 3.5 |
| Stearic (18:0) | 5.1 | 11.0 |
| Oleic (18:1) | 42.3 | 47.1 |
| Linoleic (18:2) | 19.3 | 11.0 |

**Table 3. Fat Quality Indicators of Choice White Grease and Poultry Fat**

| Item | PF | CWG |
|---|---|---|
| Total fatty acids, % | 98.7 | 97.9 |
| Free fatty acids, % | 3.2 | 3.2 |
| M.I.U., % | 1.3 | .8 |
| Peroxide value, mean/kg | .2 | 7.3 |

Following visual evaluations, the LM was traced to determine LM area. The LM and the subcutaneous fat surrounding the LM were evaluated with a Minolta Chromameter to obtain CIE L* a* b* values. Minolta L* values represent the lightness of a sample. Longissimus muscles with a higher L* value would have a lighter color, whereas those with a lower L* value would appear darker. Minolta a* values are chromatic coordinates representing a change from a green to a red color. A higher a* value represents a sample with more red color. Minolta b* values are also chromatic coordinates, representing a change in color from blue to yellow. The higher the b* value, the more yellow the color of the sample.

Longissimus samples were removed, and drip loss after 24 and 48 hours of suspension

was evaluated. This evaluation was conducted by suspending the sample on a fishhook inside a sealed Tupperware container. The weight loss of each sample was collected and reported as a percentage of the original weight. Water holding capacity was determined by measuring the expressible fluid as a ratio of total fluid area to meat film area after a sample of the LM was placed between two pieces of filter paper and pressed using a hydraulic press.

A 12-member, trained, sensory panel analyzed cooked samples of the LM from pigs fed either the control diet or diets containing 6% CWG and PF. Samples were evaluated for myofibrilar tenderness, connective tissue amount, overall tenderness, juiciness, flavor intensity, and off flavors. Myofibrilar tenderness was scored on a scale from 1 = extremely tough to 8 = extremely tender. Connective tissue amount was evaluated on a scale of 1 = abundant to 8 = none. Overall tenderness was evaluated on a scale of 1 = extremely tough to 8 = extremely tender. Juiciness was evaluated on a scale of 1 = extremely dry to 8 = extremely juicy. Flavor intensity was evaluated on a scale of 1 = extremely bland to 8 = extremely intense. Off flavor was evaluated on a scale of 1 = extremely intense to 8 = none. LM samples were evaluated for tenderness using the Warner-Bratzler shear blade attachment on the Universal Instron Testing Machine.

In an effort to determine belly firmness, the belly, with the skin side down, was laid longitudinally over a metal bar. Measurements between the cut ends of the belly were made initially and after 10 minutes to determine the amount of droop occurring in each belly. Belly lean and fat L* a* and b* values were obtained on the cut surface of the belly using the same procedures used for measurement of the LM.

A portion of the belly was cured and processed into bacon. The bacon slices were scored for sliceability and hole scores. Sliceability was evaluated on a scale of 1 = very soft and oily to 8 = very brittle and flaky. Hole scores were assessed by a scale of 1 = very high number of holes to 8 = no holes present. Cooked bacon samples were evaluated by a 12-member, trained, sensory panel for brittelness, flavor intensity, saltiness, and aftertastes. Brittleness was scored on a scale of 1 = extremely soft to 8 = extremely crisp. Flavor intensity was analyzed on a scale of 1 = extremely bland to 8 = extremely intense. Saltiness was analyzed on a scale of 1 = extremely salty to 8 = extremely unsalty. Off flavor was analyzed on a scale of 1 = none to 8 = extremely intense. Bacon samples were analyzed using the Warner-Bratzler shear force attachment on the Universal Instron Testing machine to assess toughness.

The data from this experiment were analyzed with the GLM procedure of SAS. Pigs were blocked by initial body weight. Hot carcass weight was used as a covariate with the individual pig as the experimental unit. Treatments were analyzed as a 2 × 3 factorial with control treatment. Treatment comparisons were made using orthogonal contrasts. Main effects of fat source (poultry fat or choice white grease) and fat level (2, 4, or 6%) were evaluated.

## Results and Discussion

Increasing CWG tended to increase and then decrease LM visual color (quadratic, $P<.10$; Table 4). Visual color score of the LM increased for pigs fed 4% CWG compared to longissimus muscles from pigs fed 2% CWG. This represents a progression toward a darker color. As the level of CWG in the diet increased to 6%, the color score decreased, indicating a paler color. The firmness and wetness scores of LM from pigs fed PF and CWG showed a quadratic effect. As PF or CWG levels were increased to 4%, the firmness and wetness scores increased. This indicates a firmer, less exudative sample. The scores decreased at 6%, indicating a wetter, less firm sample. Increasing CWG decreased and then increased LM Minolta L* (quadratic, $P<.10$, Table 5). Sensory analysis of LM samples indicated no differences between pigs fed the control diet and those fed either 6% CWG or PF (Table 6). Increasing PF decreased, then increased belly lean Minolta a* values and b* values ($P<.05$). Increasing CWG increased and then decreased Minolta

b* values (P<.05). As PF increased, bacon slicing scores decreased (Table 7). Bacon from pigs fed PF had higher sensory panel "off flavor" scores (P<.05) than bacon from those fed CWG. Slicing scores and off flavor scores for bacon from pigs fed PF were still within acceptable quality ranges. These data indicate that increasing levels of PF or CWG can be added to finishing pig diets with minimal influence on LM, belly, and bacon quality.

**Table 4. Effects of Choice White Grease and Poultry Fat on Finishing Pig Carcass Characteristics and Subjective Evaluations[a]**

| | | Choice White Grease, % | | | Poultry Fat, % | | | |
|---|---|---|---|---|---|---|---|---|
| Item | Control | 2 | 4 | 6 | 2 | 4 | 6 | CV |
| Backfat | | | | | | | | |
| First rib | 1.54 | 1.47 | 1.51 | 1.47 | 1.53 | 1.51 | 1.51 | 9.5 |
| Tenth rib | 0.79 | 0.74 | 0.81 | 0.78 | 0.80 | 0.78 | 0.76 | 18.6 |
| Last rib | 0.94 | 0.89 | 0.93 | 0.93 | 0.90 | 0.90 | 0.94 | 14.3 |
| Last lumbar | 0.77 | 0.67 | 0.80 | 0.75 | 0.78 | 0.77 | 0.81 | 18.6 |
| Average[b] | 1.08 | 1.01 | 1.08 | 1.05 | 1.07 | 1.06 | 1.09 | 9.7 |
| LMA, $in^2$ | 6.64 | 6.87 | 6.51 | 6.72 | 6.57 | 6.17 | 6.69 | 11.4 |
| NPPC | | | | | | | | |
| Visual color[c] | 2.50 | 2.57 | 2.67 | 2.34 | 2.46 | 2.46 | 2.45 | 16.1 |
| Visual marbling[d] | 2.61 | 2.44 | 2.56 | 2.33 | 2.40 | 2.53 | 2.20 | 26.4 |
| Visual firmness[e] | 2.86 | 2.83 | 3.02 | 2.80 | 2.66 | 2.81 | 2.66 | 16.2 |
| Longissimus WHC | | | | | | | | |
| Filter paper press, %[f] | 37.04 | 36.77 | 38.96 | 36.69 | 35.83 | 38.68 | 37.32 | 13.4 |
| Drip loss[g] | | | | | | | | |
| 24 hour, % | 2.26 | 3.19 | 2.34 | 2.88 | 2.94 | 2.41 | 3.6 | 64.2 |
| 48 hour, % | 3.91 | 4.98 | 3.94 | 4.57 | 4.58 | 3.67 | 4.81 | 54.6 |
| Pork chop cook loss[ghi] | 26.60 | 26.81 | 28.12 | 26.61 | 34.16 | 32.34 | 24.08 | 16.8 |
| Pork chop shear force | 4.13 | 4.14 | 4.06 | 4.21 | 3.99 | 4.99 | 4.14 | 32.6 |

[a]Means derived from 84 pigs (PIC, L326 × C15, initially 133 lb) slaughtered at 239 lb with six pens per treatment. Hot carcass weight was used as a covariant in the statistical analysis.
[b]Average backfat calculated as the average of first rib, last rib, and last lumbar fat depths.
[c]Scored on a scale of 1 = pale pinkish gray to 5 = dark purplish red (NPPC 1991).
[d]Scored on a scale of 1 = practically devoid to 5 = moderately abundant (NPPC, 1991).
[e]Scored on a scale of 1 = very soft and watery to 5 = very firm and dry (NPPC, 1991).
[f]Filter paper press percentage is derived by dividing the area of the meat by the area of the fluid after compression with the Carver Press.
[g]Expressed as a percentage loss of the original sample weight.
[h]Poultry fat vs choice white grease effect (P<.05).
[i]Poultry fat quadratic effect (P<.05).

**Table 5. Effects of Choice White Grease and Poultry Fat on Longissimus Muscle and Belly Objective Color[a]**

| | | Choice White Grease, % | | | Poultry Fat, % | | | |
|---|---|---|---|---|---|---|---|---|
| Item | Control | 2 | 4 | 6 | 2 | 4 | 6 | CV |
| Longissimus fat[b] | | | | | | | | |
| Minolta L*[f] | 77.76 | 77.70 | 77.28 | 77.16 | 77.74 | 77.52 | 76.54 | 1.70 |
| Minolta a* | 5.20 | 4.94 | 4.99 | 4.86 | 4.76 | 4.68 | 4.80 | 18.80 |
| Minolta b* | 5.88 | 5.86 | 5.88 | 5.79 | 5.76 | 5.92 | 5.87 | 11.30 |
| Longissimus muscle[c] | | | | | | | | |
| Minolta L*[g] | 51.54 | 50.56 | 49.50 | 52.24 | 51.58 | 50.64 | 52.06 | 5.80 |
| Minolta a* | 11.45 | 12.10 | 11.00 | 11.19 | 11.52 | 11.85 | 13.00 | 18.40 |
| Minolta b* | 7.99 | 8.02 | 7.30 | 7.92 | 8.09 | 7.95 | 8.94 | 22.80 |
| Belly fat[d] | | | | | | | | |
| Minolta L* | 79.48 | 79.54 | 79.61 | 80.26 | 79.47 | 79.57 | 79.90 | 2.60 |
| Minolta a* | 5.50 | 5.37 | 4.84 | 5.16 | 4.70 | 5.38 | 4.82 | 23.70 |
| Minolta b* | 6.24 | 6.22 | 5.80 | 6.07 | 5.94 | 6.50 | 6.04 | 12.80 |
| Belly lean[e] | | | | | | | | |
| Minolta L* | 48.17 | 47.70 | 47.65 | 47.05 | 46.84 | 46.91 | 47.00 | 5.80 |
| Minolta a* | 22.35 | 19.81 | 20.69 | 20.12 | 19.94 | 19.91 | 21.23 | 11.50 |
| Minolta b*[gh] | 9.59 | 8.35 | 8.13 | 8.67 | 8.63 | 7.82 | 8.69 | 17.40 |

[a]Means derived from 84 pigs (PIC, L326 × C15, initially 133 lb) slaughtered at 239 lb with six pens per treatment. Hot carcass weight was used as a covariant in the statistical analysis.
[b]Means derived from two readings of fat surrounding the longissimus muscle.
[c]Means derived from two readings of the longissimus at the tenth rib.
[d]Means derived from two readings of fat at the tenth rib.
[e]Means derived from two readings of the longissimus at the tenth rib.
[F]Poultry fat effect, linear (P<.05).
[g]Choice white grease effect, quadratic (P<.05).
[h]Poultry fat effect, linear (P<.05).

**Table 6. Effects of Choice White Grease and Poultry Fat (%) on Longissimus Muscle Sensory Characteristics[a]**

| Item | Control | Choice White Grease, % | Poultry Fat, % | CV |
|---|---|---|---|---|
| Flavor intensity[b] | 5.75 | 5.68 | 5.67 | 2.70 |
| Juiciness[c] | 5.74 | 5.43 | 5.35 | 6.60 |
| Overall tenderness[d] | 6.15 | 6.23 | 6.34 | 12.50 |
| Conn. tissue amount[e] | 6.96 | 6.87 | 7.04 | 6.80 |
| Myofibril tenderness[d] | 6.02 | 6.04 | 6.12 | 13.70 |

[a]Means derived from 36 pigs (PIC, L326 × C15, initially 133 lb) slaughtered at 239 lb with six pens per treatment.
[b]Scored on a scale of 1 = extremely bland to 8 = extremely intense.
[c]Scored on a scale of 1 = extremely dry to 8 = extremely juicy.
[d]Scored on a scale of 1 = extremely tough to 8 extremely tender.
[e]Scored on a scale of 1 = abundant to 8 = none.
*No statistical differences.

**Table 7. Effects of Choice White Grease and Poultry Fat on Belly Sensory, Texture, and Firmness Characteristics[a]**

| | | Choice White Grease, % | | | Poultry Fat, % | | | |
|---|---|---|---|---|---|---|---|---|
| Item | Control | 2 | 4 | 6 | 2 | 4 | 6 | CV |
| Sensory[b] | | | | | | | | |
| Aftertaste[c] | 3.94 | 3.81 | 3.86 | 3.75 | 3.77 | 4.19 | 3.88 | 12.7 |
| Off flavor[dj] | 1.26 | 1.27 | 1.24 | 1.27 | 1.39 | 1.31 | 1.38 | 15.1 |
| Saltiness[e] | 5.11 | 5.01 | 4.85 | 4.88 | 4.82 | 4.96 | 4.83 | 6.6 |
| Flavor intensity[dk] | 5.60 | 5.39 | 5.33 | 5.30 | 5.32 | 5.44 | 5.39 | 5.2 |
| Brittleness[f] | 5.27 | 5.47 | 5.28 | 5.34 | 5.38 | 5.40 | 5.21 | 10.3 |
| Bacon slicing score[gl] | 3.94 | 3.26 | 3.24 | 3.32 | 3.66 | 3.50 | 3.06 | 27.2 |
| Bacon hole score[h] | 3.26 | 2.81 | 3.42 | 3.09 | 3.45 | 2.93 | 3.27 | 23.6 |
| Bacon cooking loss[i] | 37.3 | 36.12 | 36.19 | 35.5 | 34.94 | 37.09 | 35.59 | 11.6 |
| Bacon shear force | 5.95 | 5.38 | 5.48 | 5.84 | 5.83 | 5.99 | 5.90 | 27.40 |
| Belly flexure test | | | | | | | | |
| Initial | 9.57 | 8.23 | 10.51 | 7.94 | 9.33 | 8.74 | 7.02 | 39.7 |
| Ten minutes | 7.63 | 6.49 | 8.36 | 6.42 | 6.74 | 6.86 | 5.44 | 39.3 |

[a]Means derived from 84 pigs (PIC, L326 × C15, initially 133 lb) slaughtered at 239 lb with six pens per treatment. Hot carcass weight was used as a covariant in the statistical analysis.
[b]Means derived from 12 panelists.
[c]Scored on a scale of 1 = none to 8 = extremely intense.
[d]Scored on a scale of 1 = extremely bland to 8 = extremely intense.
[e]Scored on a scale of 1 = extremely salty to 8 = extremely unsalty.
[f]Scored on a scale of 1 = extremely soft to 8 = extremely crisp.
[g]Scored on a scale of 1 = very soft and oily to 8 = very brittle and flaky.
[h]Scored on a scale of 1 = very high number of holes to 8 = no holes present.
[i]Expressed as a percentage loss of the original weight.
[j]Choice white grease vs poultry fat effect (P<.05).
[k]Choice white grease effect, linear (P<.05).
[l]Poultry fat effect, linear (P<.05).

# INFLUENCE OF DURATION OF DIETARY VITAMIN E SUPPLEMENTATION ON SWINE GROWTH PERFORMANCE AND CARCASS QUALITY [1]

***J. F. Stika, J. A. Unruh, R. D. Goodband, D. H. Kropf, and M. C. Hunt***

## Summary

Supplementing medium-lean genotype pigs with supranutritional concentrations of dietary vitamin E (91 IU *d*-α-tocopheryl acetate/lb of feed) for as long as 70 d during the finishing phase was not effective in improving swine performance, feeding characteristics, and 24 h loin muscle quality. However, lower carcass temperatures obtained by spray chilling pork sides at 0°C versus 4.4°C had a beneficial effect on 24 h carcass quality by improving marbling and lean firmness scores and reducing loin muscle moisture exudate. Overall, 24 h pork carcass quality was impacted more by chill rate than dietary vitamin E supplementation.

(Key Words: Pork, Vitamin E, Chill Rate.)

## Introduction

Improving production efficiency and meat quality have become focal points for the pork industry as attempts are made to increase its presence in the global market and as it faces increased domestic competition with other meat species. Improvements in average daily gain and feed efficiency in swine during the early stages of growth have been reported with dietary vitamin E supplementation. Yet, the effectiveness of elevated levels of vitamin E in improving swine performance during the later stages of growth is inconsistent. Pork carcass quality can be impacted greatly by several factors including animal age, diet, preslaughter stress, storage time and temperature, and meat properties such as pH. In some instances, α-tocopherol has exhibited a protective role against lipid oxidation, color deterioration, and drip loss in pork products during subsequent chilled storage and display. Faster carcass chill rates also have been shown to improve pork quality and reduce moisture losses. Therefore, variability in cooler temperature and subsequent carcass chill rate could partially impact 24 h pork carcass quality. As a result, the objectives of this study were first to evaluate the effects of duration of dietary vitamin E supplementation the growth and slaughter characteristics of finishing pigs and second, to determine the impacts of duration of vitamin E supplementation and chill temperature on 24 h pork carcass quality.

## Procedures

**Growth Performance.** Eighty crossbred medium-lean genotype barrows averaging 109 lb were allotted randomly on the basis of weight and ancestry to one of four dietary treatments. Treatments were based on the duration of *d*-α-tocopheryl acetate administration. The diets consisted of the following: (1) control diet (corn-soybean meal, .7% lysine, 12.0 IU added *d*-α-tocopheryl acetate/lb of feed); (2) control diet + added *d*-α-tocopheryl acetate (91 IU/lb of feed) for the last 42 d of the trial; (3) control diet + added *d*-α-tocopheryl acetate (91 IU/lb of feed) for the last 56 d of the trial; and (4) control diet + added *d*-α-tocopheryl acetate (91 IU/lb of feed) for the entire 70 d trial. Pigs were housed in an environmentally controlled finishing facility with complete slatted

[1]The authors thank Roche Vitamins Inc., Nutley, NJ for providing the vitamin E and partial financial support.

flooring. There were two pigs per pen (5 ft × 5 ft) and 10 replications per treatment. Each pen contained a single-hole self-feeder and a nipple waterer to accommodate *ab libitum* access to feed and water. Individual pig and feeder weights were taken every 2 wk to calculate average daily gain, average daily feed intake, and gain to feed ratios. Diets were mixed at the Kansas State University feed mill and stored in 50 lb bags. Duplicate feed samples were obtained from both the control and supplemented diets and stored at -20˚C each time a new batch was mixed to determine α-tocopherol concentration of each diet. Upon analysis, the control and supplemented diets contained 14.9 and 72.7 IU α-tocopherol/lb of feed, respectively.

**Carcass Measurements.** Approximately 12 h prior to slaughter, pigs were weighed and feed was removed. Pigs were transported to the Kansas State University abattoir, and carcasses were harvested humanely using standard industry procedures. Serum samples from each pig were collected for α-tocopherol concentration analysis. At 45 min postmortem, loin muscle pH measurements were taken on each side at the anatomical center of the loin muscle through the intercostal muscle at the 9th rib using an Orion Research model 211 pH meter. One side of each pork carcass then was chilled at 0˚C, while the opposite side was chilled at 4.4˚C. Carcasses in both coolers were sprayed with chilled water (2°C) for 10 s every 10 min during the first 10 h postmortem. Loin and ham temperatures were collected at 1, 3, 6, 12, and 24 h postmortem to monitor differences in chilling rate. Loin temperatures were collected through the 9th rib intercostal muscle at depths of 1.27 (LM1.27) and 3.81 (LM3.81) cm. Intramuscular ham temperatures were taken 2.54 cm above the aitch bone at 2.54 (H2.54) and 7.62 (H7.62) cm deep.

At 24 h postmortem, both sides of each carcass were ribbed at the 10th rib, and data were collected to determine USDA grade and percentage lean. The lb of lean pork (containing 5% fat) was calculated from 7.231 + (.437 × hot carcass weight, lb) - (18.746 × 10th rib fat depth, in) + (3.877 × 10th rib longissimus muscle area, $in^2$). Percentage lean was derived by dividing kg of lean by hot carcass weight and multiplying by 100. After a 15-min bloom period, meat exudate values were obtained by placing circular 5.5 cm-diameter filter paper on the posterior cut surface of the ribbed loin muscle for approximately 1 s. The difference between dry and moist weights was recorded as the weight of moisture exudate. CIE $L^*a^*b^*$ values of the loin muscle were measured with a Minolta CR-200 Chroma Meter. Saturation index and hue angle were calculated using the equations of $(a^{*2} + b^{*2})^{½}$ and arc tangent ($b^*/a^*$), respectively. Visual color, lean and fat firmness/wetness, and marbling of the loin muscle at the 10th rib were scored on a scale of 1 to 5 (1 = pale pinkish-gray, very soft and very watery, and devoid to practically devoid and 5 = dark purplish-red, very firm and dry, and moderately abundant or greater, respectively). A 10 g loin muscle sample was collected from the posterior ribbed surface for ultimate pH determination. Muscle samples were placed in stomacher bags with 100 ml distilled, deionized water and stomached for approximately 30 s. Sample pH then was measured at room temperature using a Fisher model 620 Accumet® pH meter equipped with a Ross® combination electrode.

**Fabrication.** At 4 d postmortem, 10 carcasses within each dietary treatment were selected randomly, and both sides were fabricated to obtain the loin muscle from the 11th rib to the 4th lumbar vertebra. Six 1 in-thick boneless loin chops were collected beginning at the 12th rib and proceeding posteriorly. The final three chops collected were utilized, from anterior to posterior, to determine loin muscle Warner-Bratzler shear (WBS) force and cook loss percentage, expressible fluid values, and muscle composition, respectively.

**Shear Force and Cook Loss Percentage Determination.** Fresh loin chops were weighed and cooked to an internal temperature of 70˚C in a Blodgett dual-air-flow oven. Chop internal temperature was

monitored with thermocouples attached to a DORIC Minitrend 205 temperature monitor. After a 2 h cooling period at room temperature, chops were blotted and reweighed. Six 1.27 cm-diameter cores were removed with a mechanical coring device parallel to the muscle fibers and sheared once through the center with a Warner-Bratzler shear (WBS) device attached to an Instron 4201 machine. The six values were averaged to determine a WBS value for statistical analysis. Cooking loss percentage for loin chops was calculated by 100 x (fresh chop weight - cooked chop weight)/fresh chop weight.

**Expressible Fluid Determination.** Fresh loin muscle samples ranging from 500 to 750 mg were obtained from the interior of each chop and placed individually in the center of a circular piece of filter paper 15 cm in diameter. The filter paper and muscle samples then were placed singly between two plexiglass plates and pressed with a Carver Press for 5 min at 5,000 psi. Expressible fluid was presented as the ratio of total fluid area to meat film area. Larger values suggest lower water holding capacity.

**Proximate Analysis.** A boneless 1-in. loin chop obtained from each side chilled at 0˚C was trimmed free of subcutaneous fat and connective tissue. Samples were analyzed for percent dry matter (DM), ether extractable lipid, crude protein (CP), and ash.

**Serum α-Tocopherol Analysis.** α-Tocopherol was extracted from .4 ml of plasma using 2 ml of hexane. The hexane layer was removed and dried under a gentle stream of $N_2$ in a water bath at 50˚C. The residue was dissolved in .4 ml of ethanol, and α-tocopherol concentration was determined using high pressure liquid chromotography.

**Statistical Analysis.** The experiment was analyzed as a randomized complete block, using initial weight to establish blocks. Growth performance data and carcass slaughter characteristics were analyzed using the GLM procedure of SAS with pen serving as the experimental unit. Data collected on pigs randomly selected within each dietary treatment across blocks were analyzed using the Mixed procedure of SAS. Diet, chill temperature, and the interaction of diet x chill temperature were treated as fixed effects. Carcass measurements collected at 24 h were analyzed as a split-plot design with diet as the whole-plot factor and chill temperature as the subplot factor. For comparisons pertaining to measurements over time, a split-split-plot analysis was conducted to account for repeated measures. Diet served as the whole-plot factor, chill temperature as the subplot factor, and time as the sub-sub-plot factor. Satterthwaite adjusted degrees of freedom were used during Mixed procedure analysis to test significance among main effects and interactions. All main effect and interaction means were separated using least squares procedures when the respective F-tests were significant ($P<.05$).

## Results and Discussion

**Growth Performance and Carcass Traits.** Supplementation of swine diets with 91 IU *d*-α-tocopheryl acetate/lb of feed for 42, 56, or 70 d prior to slaughter did not influence growth and feeding characteristics compared to control pigs fed 12 IU/.b of feed. No differences ($P>.10$) in ADG, ADFI, and F/G ratio resulted from dietary vitamin E supplementation over the duration of the trial. Carcass slaughter measurements also were similar ($P>.10$) among dietary groups (Table 1), presumably because of the lack of differences in growth rate.

**Serum α-Tocopherol Concentration and Proximate Analysis.** Plasma α-tocopherol concentration was influenced by dietary vitamin E supplementation. α-Tocopherol concentrations were higher ($P<.05$) in plasma from pigs supplemented with 91 IU *d*-α-tocopheryl acetate/lb of feed for 70 d than in plasma from control pigs (12 IU/lb of feed for 70 d). Plasma α-tocopherol concentrations for supplemented and control pigs were 6.4 ± .10 μg/ml and 4.0 ± .09 μg/ml, respectively. The plasma α-tocopherol concentration of pigs supplemented with 200 IU/kg of feed was as predicted. However, the plasma α-tocopherol concentration for pigs fed the control diet was higher than expected. This

related to higher than expected α-tocopherol concentrations in the control diet. Diet also did not influence (P>.10) proximate analysis values of loin muscles.

**Carcass Chill Rate.** Sides chilled at 0˚C cooled faster (P<.01) during the first 2 h in the cooler compared to those chilled at 4.4˚C when monitored at LM1.27, LM3.81, and H2.54. After this time period, side chill rates were similar (P>.10). Temperatures taken at H7.62 were numerically lower at 3, 6, and 12 h postmortem for sides chilled at 0˚C, although not statistically different (P>.05) from those chilled at 4.4°C. However, temperatures at all locations were lower (P<.01) for carcasses chilled at 0°C compared to 4.4°C at 24 h postmortem.

**Loin Muscle Quality Traits.** Visual color, marbling, lean firmness/wetness, and fat firmness values did not differ (P>.10) as a result of dietary vitamin E supplementation. Although visual color values were similar (P>.10), pork sides chilled at 0˚C exhibited more (P<.01) visual marbling in a firmer, drier loin muscle. The backfat of sides chilled at 0°C also was firmer (P<.01) compared to sides chilled at 4.4˚C (Table 2). No diet × chill temperature interaction was detected (P>.10). Sides chilled at 0˚C also exhibited less (P<.01) loin muscle surface moisture exudate compared to those chilled at 4.4˚C (Table 2). Neither a diet main effect nor a diet × chill temperature interaction was detected. The improvements in visual pork quality and loin muscle surface moisture exudate are attributable to lower (P<.01) loin muscle temperatures after 24 h of chilling at 0˚C compared to 4.4˚C, because ultimate carcass pH values did not differ (P>.10).

Diet and chill temperature main effect means were similar (P>.10) for CIE *L*a*b** measures, saturation index, and hue angle at 24 h postmortem. Although neither a chill temperature main effect nor diet × chill temperature interaction was detected (P>.10) for cooking loss, dietary treatment did impact cooking loss percentages. Chops from pigs supplemented with 91 IU/lb of feed for 56 d exhibited less (P<.01) cooking loss than chops from pigs in other dietary treatment groups. This lower percentage was difficult to attribute to vitamin E supplementation, because both the 42 and 70 d supplementation treatment groups were similar (P>.10) to controls.

**Table 1. Effects of Duration of α-Tocopheryl Acetate Supplementation Swine Growth Performance and Carcass Characteristics[a]**

| | 91IU α-Tocopheryl Acetate/Lb of Feed | | | | |
|---|---|---|---|---|---|
| Item | Control | 42 d | 56 d | 70 d | SE[b] |
| ADG, lb | 2.09 | 1.90 | 1.90 | 1.90 | .09 |
| ADFI, lb | 7.05 | 6.83 | 6.39 | 6.83 | .18 |
| G/F | 3.37 | 3.600 | 3.36 | 3.59 | .16 |
| Slaughter wt., lb | 261.9 | 263.0 | 257.9 | 261.0 | 4.15 |
| Hot carcass wt., lb | 198.9 | 199.3 | 195.3 | 199.1 | 3.33 |
| Dressing percentage | 75.9 | 75.6 | 75.7 | 76.3 | .24 |
| USDA grade | 2.6 | 2.4 | 2.4 | 2.5 | .07 |
| Percentage lean (5% fat) | 44.5 | 44.8 | 45.4 | 44.1 | .67 |
| Loin muscle area, $in^2$ | 5.30 | 5.50 | 5.38 | 5.10 | .16 |
| $10^{th}$ rib fat thickness, in | 1.40 | 1.40 | 1.32 | 1.41 | .05 |

[a]No treatment differences (P>.05).
[b]Standard error.

**Table 2. Effects of Chill Temperature on Measurements of 24 h Pork Carcass Quality**

| | Chill Temperature | | |
|---|---|---|---|
| Item | 0°C | 4.4°C | SE[a] |
| Visual appraisal[b] | | | |
| Color | 2.7 | 2.7 | .04 |
| Marbling | 2.7[d] | 2.3[e] | .04 |
| Lean firmness/wetness | 3.2[d] | 2.9[e] | .06 |
| Fat firmness | 3.8[d] | 3.6[e] | .03 |
| Loin muscle moisture exudate, g | .044[d] | .052[e] | .00 |
| CIE color measurements[c] | | | |
| L* | 50.5 | 50.0 | .18 |
| a* | 8.3 | 8.2 | .07 |
| b* | 5.4 | 5.3 | .07 |
| Saturation index | 9.9 | 9.8 | .11 |
| Hue angle | 33.1 | 32.9 | .24 |

[a]Standard error.
[b]Scores of 1 to 5: 2 = grayish pink, traces to slight, or soft and watery; 3 = reddish pink, small to modest, or slightly firm and moist; and 4 = purplish red, moderate to slightly abundant, or firm and moderately dry.
[c]Measure of dark to light (L*), redness (a*), yellowness (b*), vividness or intensity (saturation index), or red to orange (hue angle).
[de]Means in the same row with a different superscript letter differ (P<.05).

# INFLUENCE OF DURATION OF DIETARY VITAMIN E SUPPLEMENTATION ON FRESH AND CURED PORK COLOR STABILITY [1]

***J. F. Stika, J. A. Unruh, D. H. Kropf, R. D. Goodband, and M. C. Hunt***

## Summary

Supplementing finishing pigs genetically predisposed to lipid deposition with α-tocopheryl acetate above 12 IU/lb of feed for as long as 70 d did not improve color stability of fresh and cured pork. Tissue α-tocopherol levels were similar across dietary treatments and higher than predicted. Muscle accumulation of α-tocopherol may be related to the rate and extent of lipid deposition in muscle. Also, chill temperature and carcass chill rate variability, under spray chill conditions, did not influence fresh pork color stability when carcasses with excessive amounts of external fat were utilized.

(Key Words: Pork, Vitamin E, Chill Rate.)

## Introduction

Inadequate color is a major quality concern identified by all members of the pork marketing chain. The importance of visual appearance stems from its strong influence on consumer purchasing decisions at the retail case. Consumers discriminate against meat cuts that lack a fresh appearance and often misinterpret color blemishes as an indication of unwholesomeness. As a result, meat that becomes discolored is either marketed at a reduced price or is processed and merchandised in a reduced-value form at the expense of the industry.

Vitamin E is a potent antioxidant that has exhibited a dominant effect on preventing discoloration and extending color display life of beef, lamb, and pork. However, the ability of vitamin E to improve the color stability of fresh vacuum-packaged pork and cured pork products has not been determined. Therefore, the objectives of this research were to examine the effects of added dietary α-tocopherol and chill temperature on fresh loin chop color stability and to determine the influence of added dietary vitamin E on the cured color of inside ham muscles during retail display.

## Procedures

**Experimental Animals.** Eighty medium-lean genotype crossbred barrows averaging 49.5 kg were allotted to one of four dietary treatments. Treatments were based on the duration of *d*-α-tocopheryl acetate administration. Pigs were fed either a control diet (corn-soybean meal, .7% lysine) containing 12.0 IU added *d*-α-tocopheryl acetate/lb of feed for 70 d or a diet supplemented with 91 IU *d*-α-tocopheryl acetate/lb of feed for 42, 56, or 70 d prior to slaughter. Pigs were housed in an environmentally controlled finishing facility with complete slatted flooring. There were two pigs per pen (5 ft × 5 ft) and 10 replications per treatment. Each pen contained a single-hole self-feeder and a nipple waterer to accommodate ab libitum access to feed and water. All carcasses were harvested humanely at the Kansas State University meat laboratory using standard industry procedures. Both sides of each carcass were sprayed with chilled water (2°C) for 10 s every 10 min during the first 10 h in the cooler; one side was chilled at 0°C, and

[1]The authors thank Roche Vitamins Inc., Nutley, NJ for providing the vitamin E and partial financial support.

the other at 4.4˚C. At 4 d postmortem, 10 carcasses within each dietary treatment were selected randomly, and both sides were fabricated to obtain the loin muscle from the 11th rib to the 4th lumbar vertebra. Six 1-in.-thick boneless loin chops were collected beginning at the 12th rib and proceeding posteriorly. The initial three chops collected were utilized, from anterior to posterior, to determine polyvinyl chloride (PVC) and vacuum-packaged fresh color stability and tissue α-tocopherol concentration, respectively. *Semimembranosus* and *adductor* muscles (inside ham muscles) from all sides chilled at 0°C within the control group and the group that received 91 IU/lb of feed for 70 d also were collected for cured color analysis. *Semimembranosus* samples were obtained at the time of fabrication for tissue α-tocopherol determination.

**Tissue α-Tocopherol Concentration.** α-Tocopherol was extracted from muscle tissue using iso-octane. Samples were saponified with KOH at 78°C prior to extraction. Normal-phase, isocratic liquid chromatography with a fluorescence detector (excitation 296 nm; emission 325 nm) was utilized to quantify α-tocopherol.

**Fresh Color Evaluation.** Chops were either placed on Styrofoam trays with absorbent pads and overwrapped with oxygen permeable PVC film or packaged in 4 in. × 10 in., 3 mil, standard, barrier nylon/PE vacuum pouches. All chops were displayed in an open-topped display case at 2 ± 2°C under 1614 lux (150 foot candles) of deluxe warm white fluorescent lighting. An experienced eight-member sensory panel evaluated both PVC- and vacuum-packaged chops. Chops packaged in PVC were evaluated at 0, 1, 3, 5, 7, and 10 d of retail display and assigned color scores on a scale of 1 to 5 (1 = very dark pink or brown; 2 = dark pink or brown; 3 = slightly dark pink; 4 = bright pink; and 5 = very bright pink). Vacuum-packaged chops were evaluated at 0, 1, 3, 7, and 14 d of retail display using a similar scale of 1 to 5 (1 = brown; 2 = brownish pink; 3 = slightly brownish pink; 4 = purplish pink; 5 = bright purplish pink). CIE *L*a*b** values also were measured at these times using a Hunterlab LabScan 6000 Spectrocolorimeter. Three readings were averaged to determine the final *L**, *a**, and *b** values for each chop.

**Cured Color Evaluation.** Cured/cooked hams were produced by pickle injection (10 % of the weight) using a 5-needle, hand-stitch, brine pump injector at 50 p.s.i. The pickle composition (% w/w) was 15 % sodium chloride, 0.075 % nitrite, 3 % phosphate, and 81.9 % water. Ingredient concentrations and percentage pump were established to deliver a final product with a 2.0% salt concentration. Following a 2 d equilibration period, hams were stuffed into cellulose casings and cooked to an internal temperature of 70°C. A 1-in.-thick cross-sectional slice was removed from the center of each ham and vacuum packaged in 3 mil, standard, barrier nylon/PE vacuum pouches. Slices were displayed in an open-topped display case as described previously. The *semimembranosus* of each slice was evaluated for cured color by an experienced eight-member sensory panel at 0, 1, 3, 6, 9, 17, and 23 d using a scale of 1 to 6 (1 = tan or gray; 2 = grayish tan; 3 = very slightly pink; 4 = slightly pink; 5 moderately pink; 6 = pink). CIE *L* a* b** were collected at these times using a Hunterlab LabScan 6000 Spectrocolorimeter. Three readings per slice were averaged to determined final instrumental color values.

**Statistical Analysis.** This experiment was analyzed as a randomized complete block, using initial weight to establish blocks. All data were analyzed using the Mixed procedure of SAS. Diet, chill temperature, display time, and the corresponding two-way and three-way interactions were treated as fixed effects. For comparisons pertaining to measurements over time, either a split-split-plot or a split-plot analysis was conducted to account for repeated measures. Diet served as the whole-plot factor, chill temperature as the subplot factor, and display time as either the sub-subplot or subplot factor as determined by the presence or absence of a chill temperature variable. Satterthwaite adjusted degrees of freedom were used to test significance among main effects and interactions. Main effect and interaction means were separated using least squares procedures

when the respective F-tests were significant (P<.05).

## Results and Discussion

**Tissue α-Tocopherol Concentration.** Feeding pigs a diet containing 91 IU added α-tocopheryl acetate/lb of feed for either 42, 56, or 70 d resulted in similar (P>.10) loin and *semimembranosus* α-tocopherol concentrations compared to control (12.0 IU/lb of feed) pigs. Supplementing pigs with 91 IU/lb of feed for 42, 56, and 70 d resulted in loin muscle α-tocopherol concentrations of 13.5, 12.5, and 13.8 µg/g of tissue, respectively, whereas control pigs had a mean loin muscle α-tocopherol level of 14.9 µg/g of tissue. Although differences were not detected, all dietary treatment groups had higher muscle α-tocopherol concentrations than expected. The highest levels of α-tocopherol in pork are detectable in adipose tissue, primarily because of the solubility of vitamin E in lipid. This suggests that muscle tissue lipid content may positively influence muscle α-tocopherol concentration. Therefore, the higher than expected muscle α-tocopherol concentrations across dietary treatments observed may have been influenced partially by the high muscle lipid content of the medium-lean genotype barrows utilized in this study. The population utilized had an average loin muscle lipid content of 4.71 ± .41 %. This is approximately 25% to 45% greater than expected for pigs of this genotype and 44% and 57% more than muscle tissue lipid of high-lean genotype barrows and gilts, respectively, often used in similar vitamin E studies. In addition to genetics, slaughter weight also may potentially influence tissue α-tocopherol levels because lipid deposition increases as pigs are fed to heavier weights. The barrows in this study were slaughtered at an average live weight of 261 ± 4 lb and had a mean 10th rib fat measurement of 1.4 ± .03 in. These results suggest that differences in slaughter weight, composition, and maturity may contribute to muscle α-tocopherol levels. Therefore, we speculate that when swine populations predisposed to lipid deposition are fed to heavier weights, muscle α-tocopherol accumulation may be accelerated. Also, supplementation of dietary vitamin E at levels greater than 12.0 IU/lb of feed does not appear to influence muscle α-tocopherol levels under these conditions.

**Fresh Pork Color.** Neither dietary α-tocopherol supplementation nor chill temperature main effects were detected (P>.10) for any visual sensory panel color scores and instrumental color measurements for PVC-packaged chops (Table 1). However, as expected, a display time main effect existed (P<.01) for visual sensory panel color scores, CIE $L^*a^*b^*$ values, saturation index, and hue angle (Table 2). Visual sensory panel color scores revealed a dramatic decline in fresh color over 10 d. Instrumental measures also indicated color deterioration over time. Lightness ($L^*$) values were higher (P<.05) at 0, 1, and 3 d of display than at 5, 7, and 10 d and were higher at 7 d than at 5 and 10 d. Overall, $L^*$ values appeared to decline after 3 d of display. Redness ($a^*$) values of PVC-packaged chops declined at a more rapid rate than $L^*$ and $b^*$ values. Redness ($a^*$) values progressively decreased, with lower (P<.05) values obtained at 1, 3, 5, and 7 d of refrigerated display. Further decreases were not manifested; $a^*$ values after 10 d were similar (P>.05) to those at 5 and 7 d. CIE $b^*$ values also gradually declined; they were higher (P<.05) at 0 and 1 d than at 3, 5, 7, and 10 d. Values for $b^*$ were similar (P>.05) at 3 and 5 d of display and at 5 and 7 d, whereas $b^*$ values after 10 d were lower (P<.05) than all others. Color intensity (saturation index) values differed (P<.05), with lower values observed at 1, 3, and 5 d of display. Saturation index values were similar (P>.05) at 5 and 7 d and at 7 and 10 d. Hue angle exhibited a slow increasing trend; values differed (P<.05) at 1 and 5 d of display.

The lack of differences in color stability with vitamin E supplementation in fresh PVC-packaged pork chops may be a reflection of similar muscle tissue α-tocopherol concentrations. Improvements in pork color from supplementation with dietary vitamin E have been suggested to be related directly to the amount of α-tocopherol incorporated into the muscle tissue. Our results indicate that elevated concentrations of vitamin E in mus-

cle tissue do not guarantee an improvement in fresh color stability.

Results similar to those reported for chops packaged with PVC film were obtained for fresh pork chops displayed in vacuum pouches. All reported visual sensory panel color scores and instrumental color measures were similar (P>.10) across chill temperatures. A diet main effect was detected (P<.05) only for hue angle. The difference in hue angle means was difficult to attribute specifically to dietary vitamin E supplementation, because a relationship with loin muscle α-tocopherol concentration did not exist. Hue angle values were similar (P>.05) for chops from control pigs and pigs supplemented for 42, 56, and 70 d. However, hue angle values were lower (P<.05) for chops from pigs supplemented for 42 and 56 d compared to 70 d. Visual sensory panel color scores, *L** values, *b** values, and hue angle means for vacuum-packaged chops differed (P<.05) as a result of display time. Visual sensory panel color scores declined (P<.05) at each evaluation period. CIE *L** values were lower (P<.05) at 1 d of display than at 3 and 7 d and were lower at 3 and 7 d than at 14 d. Overall, gradual increase in *L** values occurred over 14 d of retail display. Both *b** and hue angle values decreased (P < .05) at 3 d and then remained unchanged during additional display. Both *a** and saturation index values remained constant (P>.10) over the 14 d of display.

**Cured Pork Color.** Means for visual sensory panel color scores and all instrumental color measures were similar (P>.10) for ham slices from both control pigs and pigs supplemented for 70 d. Visual sensory panel scores, *L*a*b** values, and hue angle means differed (P<.05) with longer display time. Color scores were more intensely pink (P<.05) at 0 and 1 d of display, then declined (P<.05) at 3, 6, 9, 17, and 23 d. The measurable decrease in color stability observed visually was supported by instrumental measures. Values for *L** were similar (P<.05) at 0, 1, 3, 6, 9, and 23 d but were higher at 17 d (P<.05). Values for *a** were unchanged (P>.05) through 6 d of display. Values for *a** also were similar (P>.05) at 1, 3, 6, 9, and 23 d, and values at 17 d were less than those at 0 and 1 d. Values for *b** were higher (P<.05) at 1 d of display and again (P<.05) at 23 d. Although saturation index was not influenced by increases in display length, hue angle values increased. Hue angle values were lower (P<.05) at 0 d compared to all other times, and increased gradually up to 23 d. Improvements in the flavor attributes of cured hams from pigs supplemented with 91 mg α-tocopheryl acetate/lb of feed have been reported, but vitamin E was not effective in improving cured color stability in this study.

However, the need to reduce the susceptibility of cured color to deterioration merits further research.

**Table 1. Effects of Duration of Vitamin E Supplementation and Chill Temperature on Fresh Color of Pork Loin Chops Overwrapped in PVC and Displayed at 2°C[a]**

| | | 91 IU/Lb of Feed | | | | Chill Temp. | | |
|---|---|---|---|---|---|---|---|---|
| Item | Control | 42 d | 56 d | 70 d | SE[b] | 0°C | 4.4°C | SE |
| Visual color score[c] | 3.2 | 3.1 | 3.2 | 3.2 | .09 | 3.2 | 3.2 | .02 |
| Instrumental color[d] | | | | | | | | |
| L* | 58.3 | 56.9 | 55.1 | 58.6 | 1.15 | 57.2 | 57.2 | .77 |
| a* | 17.6 | 18.0 | 18.5 | 18.1 | .39 | 18.0 | 18.0 | .27 |
| b* | 16.3 | 16.3 | 15.0 | 16.4 | .48 | 16.1 | 15.9 | .33 |
| Saturation index | 24.1 | 24.4 | 23.9 | 24.4 | .38 | 24.3 | 24.1 | .28 |
| Hue angle | 43.1 | 42.1 | 39.3 | 42.4 | 1.23 | 41.9 | 41.6 | .83 |

[a]No treatment differences (P>.05).
[b]Standard Error.
[c]Scores of 1 to 5: 2 = dark pink or brown; 3 = slightly dark pink; 4 = bright pink.
[d]Measure of dark to light (L*), redness (a*), yellowness (b*), vividness or intensity (saturation index), or red to orange (hue angle).

**Table 2. Effects of Display Length at 2°C on Visual and Instrumental Color Measurements of Fresh Pork Loin Chops Overwrapped in PVC**

| | Display Length, d | | | | | | |
|---|---|---|---|---|---|---|---|
| Item | 0 | 1 | 3 | 5 | 7 | 10 | SE[a] |
| Visual color score[b] | 4.3[d] | 4.1[e] | 3.6[f] | 2.9[g] | 2.3[h] | 1.9[i] | .05 |
| Instrumental color[c] | | | | | | | |
| L* | 57.9[d] | 57.9[d] | 57.9[d] | 56.4[f] | 57.2[e] | 56.0[f] | .77 |
| a* | 21.9[d] | 20.3[e] | 18.9[f] | 16.2[g] | 15.4[h] | 15.6[gh] | .34 |
| b* | 17.3[d] | 17.4[d] | 16.3[e] | 15.6[ef] | 15.1[f] | 14.3[g] | .38 |
| Saturation index | 28.0[d] | 26.8[e] | 24.9[f] | 22.6[g] | 21.8[gh] | 21.4[h] | .38 |
| Hue angle | 38.1[d] | 40.5[e] | 40.8[e] | 43.8[f] | 44.2[f] | 43.1[f] | .89 |

[a]Standard Error.
[b]Scores of 1 to 5: 1 = very dark pink or brown; 2 = dark pink or brown; 3 = slightly dark pink; 4 = bright pink; 5 = very bright pink.
[c]Measure of dark to light (L*), redness (a*), yellowness (b*), vividness or intensity (saturation index), or red to orange (hue angle).
[d,e,f,g,h,i]Means in the same row with a different superscript letter differ (P<.05).

*Swine Day 1998*

# INFLUENCE OF CHOP LOCATION ON BONELESS PORK LOIN QUALITY [1]

*A. T. Waylan, J. A. Unruh, and R. C. Johnson* [2]

## Summary

Eighty-two boneless pork loins were used to examine the effects of chop location on longissimus muscle quality. The highest quality chops came from the posterior end. They had the lowest Warner-Bratzler shear value (most tender), highest cooking yield, and a high pH and percent extractable lipid. Visual and instrumental data suggested that the most posterior chop was lighter colored and had the highest degree of marbling. Color, firmness, and marbling evaluations were similar in the central posterior section of the loin. This suggests that this section was very uniform in visual pork quality. The anterior portion of the loin was more variable in uniformity of pork quality. The most anterior chops (17 and 19 in from posterior end) were darker but softer and more watery than chops 13 and 15 in from the posterior end. Our study suggests that locations within a loin may vary in quality characteristics, color, tenderness, cooking yield, pH, and lipid (marbling).

(Key Words: Pork, Longissimus Muscle, Quality.)

## Introduction

Fresh pork quality has been defined as a combination of traits that include appearance, taste, nutritional value, and wholesomeness. Color is a primary quality factor considered when meat is purchased, along with other visual characteristics. Consumer concerns about meat quality have led livestock producers, packers, processors, purveyors, and retailers to consider production practices that affect pork quality, value, and consistency. Genetics, slaughter practices, and chill conditions affect pork quality. However, chop location within a loin may also contribute to inconsistency in pork quality. Therefore, the objective of this study was to determine the influence of chop location within a boneless loin on quality characteristics.

## Procedures

Eighty-two boneless pork loins were obtained from a commercial packing facility. They were selected from hogs with similar carcass weights (between 180 and 210 lb) and had similar lengths (20-22 in). At 7 d postmortem, the loins were cut from posterior to anterior ends into 1 in chops. Chop surfaces were allowed to bloom for 30 min before the Longissimus muscle (LM) was evaluated at 1, 3, 5, 7, 9, 11, 13, 15, 17, and 19 in, posterior to anterior. Visual color, firmness and wetness, and marbling were evaluated using NPPC (1991) guidelines. Visual color was evaluated on a 1 to 5 scale, with 1 representing a muscle that was pale-pinkish-gray and 5 being a muscle that was dark-purplish red in color. Visual firmness and wetness were evaluated on a 1 to 5 scale, with 1 being very soft and watery and 5 being very firm and dry. Visual marbling was evaluated on a 1 to 5 scale, with 1 being practically devoid and 5 being moderately abundant or greater. Following the visual

[1]The authors thank Dekalb Swine Breeders, Inc., Plains, KS for their partial financial support.

[2]Meat Science Program Manager, Dekalb Swine Breeders, Inc.

evaluations, L*a*b* values were measured utilizing a HunterLab Miniscan (Hunter and Associates, Reston, VA) with a 10° observer and Illuminant C. Each chop was scanned at two locations (lateral and medial) within the LM and averaged. The L* value is a measure of lightness (0 to 100), the a* value measures green to red (-60 to 60), and the b* value measures blue to yellow (-60 to 60).

Chops at 2, 7, 12, and 17 in, posterior to anterior, were used to determine thawing and cooking losses, as well as Warner-Bratzler shear (WBS) evaluations. Chops were frozen and held at -40ºF, thawed at 38ºF for 24 h, and then weighed and cooked to an internal temperature of 160°F in a Blodgett dual-air-flow oven. Temperature was monitored using thermocouples attached to a Doric Minitrend 205 temperature monitor. Chops were cooled at room temperature for 1 h and reweighed. Chops then were chilled 24 h at 38°F before six .5 in cores were taken parallel to the muscle fibers and sheared perpendicular to the muscle fibers using a Universal Instron.

Forty of the above boneless pork loins were selected randomly to determine excess water binding capacity, cooking yield, and percents extractable lipid and moisture. Water binding capacity, cooking yield values, and pH measurements were taken on four chops at 4, 9, 14, and 19 in, posterior to anterior. Excess water binding capacity and cooking yield were determined by grinding the longissimus muscle through a .125 in plate, randomly selecting a 15 ± .05 g sample, and mixing it with a .6 M NaCl and .04 M $Na_2HPO_4$ solution. The mixture was centrifuged and cooked in a 176°F water bath for 30 min. Excess water binding capacity is an indication of the total amount of hydrating solution the ground meat is capable of holding. The equation used was [(((total weight before cooking – tube weight) – 15)/15) × 100]. Cooking yield is an indication of the capability of meat proteins to bind water upon cooking. It is the proportion of the uncooked, hydrated meat pellet retained after heating and centrifugation. The equation used was [((total weight after cooking – tube weight)/(total weight before cooking – tube weight)) × 100]. pH was measured using a Metoxy stainless steel pH electrode and meter (Model HM-17MX; TOA Electronics, Ltd., Tokyo, Japan).

Four chops located at 3, 8, 13, and 18 in, posterior to anterior were analyzed for percent extractable lipid and moisture using AOAC (1992) procedures.

## Results and Discussion

Visual characteristics for chop surfaces taken at 2-in intervals are reported in Figure 1. The LM chop surfaces were more reddish-pink ($P<.05$) at 3 to 11 in from the posterior end than surfaces of chops located at 1, 13, and 15 in from the posterior end. The chop at 19 in from the posterior end of the loin (anterior portion) was darker, more ($P<.05$) reddish-pink than all other chops. In general, chops became softer and more watery from the posterior to anterior locations. Chops located 1 through 9 in from the posterior end were firmer and less watery ($P<.05$) than chops located between 13 and 19 in from the posterior end. In addition, chops at 17 and 19 in from the posterior end were the softest and most watery ($P<.05$). Visual marbling was higher ($P<.05$) at the posterior end (chops located 1 and 3 in from the posterior end) than for the rest of the loin (chops located 5 through 19 in from the posterior end).

Instrumental values (L*, a*, and b*) are presented in Figures 2 to 4. Values for L*, measure of lightness were darker ($P<.05$) for chops located 3 to 11 in from the posterior end than for chops from the posterior end (1 in) and anterior end (13 and 15 in from the posterior end). The most anterior chops (17 and 19 in from the posterior end) also were darker ($P<.05$) than chops located 13 and 15 in from the posterior end. The a* values (measure of redness) of the anterior chops (17 and 19 in from the posterior end) were redder ($P<.05$) than those for the rest of the loin. Chops located at 13 and 15 in from the posterior end were ($P<.05$) more yellow than chops located 9 and 19 in from the posterior end.

Both visual and instrumental data suggest that the most posterior chop was lighter colored but had a high degree of marbling and firmness. Through the central posterior section (3 to 11 in from the posterior end), chops had somewhat similar color, firmness, and marbling evaluations. This suggests that this section was very uniform in pork quality. The anterior portion of the loin was more variable in quality. Chops 13 and 15 in from the posterior end, which are below the spinalis dorsi (cap muscle), were lighter colored and generally softer than chops from the adjoining posterior central location. The most anterior chops (17 and 19 in from the posterior end) were darker and tended to have more intramuscular lipid but were softer and more watery than chops from 13 and 15 in from the posterior end.

The LM quality characteristics are presented in Table 1. The posterior chop (2 in from the posterior end) had the lowest (P<.05) WBS value (most tender). The central anterior chop (12 in from the posterior end) had a lower WBS value (more tender) than the central posterior chop (7 in from the posterior end). Although no differences were detected (P>.05) for cooking and thawing losses and excess water binding values, the posterior chop had a higher (P<.05) cooking yield than those from the other locations. The anterior end (19 in from the posterior end) had the highest (P<.05) pH, and the posterior end (4 in from the posterior end) had a higher pH than the central anterior location (14 in from the posterior end). Chops from the anterior (18 in from the posterior end) and posterior (3 in from the posterior end) locations had more extractable lipid than the central posterior (8 in from the posterior end) location.

The highest quality chops appear to come from the posterior end. They had the lowest WBS value (most tender), highest cooking yield, and a high pH and percent extractable lipid. The higher lipid content corresponded with the higher visual marbling score. However, the other three sections were more variable in quality-related traits.

This study suggests that locations within the same loin may vary in color, tenderness, cooking yield, pH, and lipid (marbling). However, some sections within the same loin have similar quality characteristics. Therefore, pork loins potentially can be sectioned to increase the consistency of quality characteristics and provide a more uniform purchasing unit for consumers.

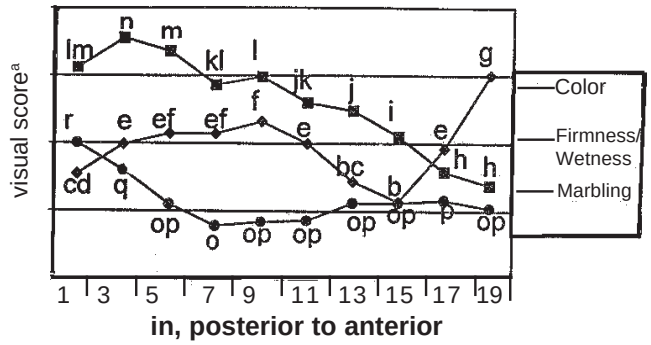



**Figure 1. The Influence of Chop Location on VisuaI Characteristics.**

[a]5-point scale (2=grayish pink, soft and watery, or traces to slight; 3=reddish-pink, slightly firm and moist, or small to modest; 4= purplish red, firm and moderately dry, or moderate to slightly abundant) [b,c,d,e,f,g]Means for visual color without a common superscript differ (P<.05). [h,i,j,k,l,m,n] Means for visual firmness and wetness without a common superscript differ (P<.05). [o,p,q,r]Means for visual marbling without a common superscript differ(P<.05).

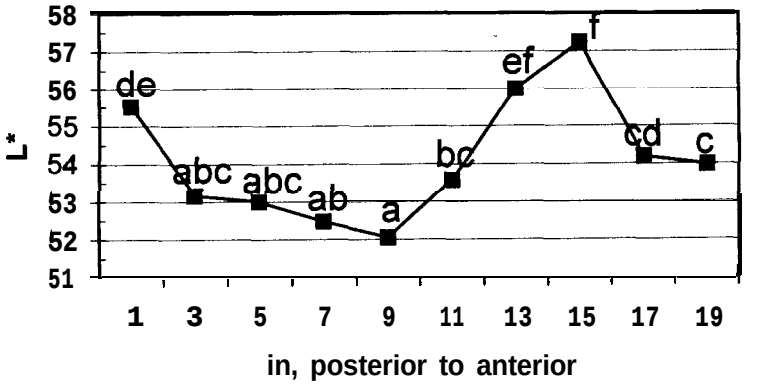



**Figure 2. The Influence of Chop Location L* Values.**

[a,b,c,d,e,f]Means without a common superscript letter differ (P<.05).

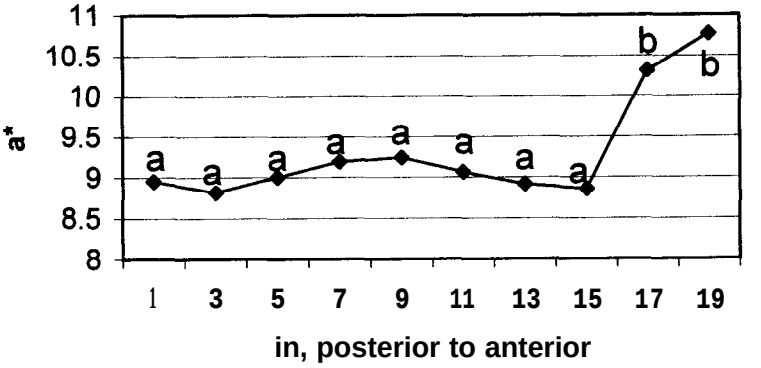



**Figure 3. The Influence of Chop Location on Longissimus Muscle a* Values.**

[a,b]Means without a common superscript letter differ (P<.05).

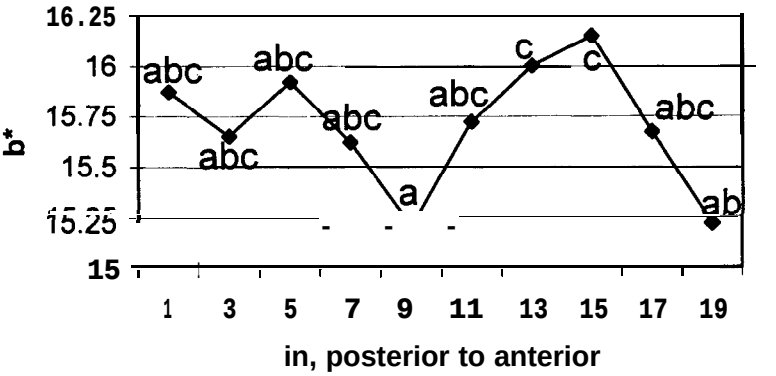



**Figure 4. The Influence of Chop Location on Longissimus Muscle b* Values.**

[a,b,c]Means without a common superscript letter differ (P<.05).

**Table 1. The Influence of Chop Location on Longissimus Muscle Quality Characteristics**

| | Posterior | | Central | | Central Anterior | | Anterior | |
|---|---|---|---|---|---|---|---|---|
| Item | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| WBS[a], lb[b] | 6.33[e] | .047 | 7.05[g] | .047 | 6.72[f] | .048 | 6.81[fg] | .050 |
| Cooking loss, %[b] | 21.90 | .480 | 21.93 | .480 | 22.02 | .480 | 21.02 | .480 |
| Thawing loss, %[b] | 2.78 | .063 | 2.94 | .063 | 2.98 | .063 | 2.83 | .063 |
| Excess water[c] | 62.72 | 3.92 | 69.08 | 3.92 | 64.58 | 3.92 | 57.85 | 3.97 |
| Cooking yield[c] | 73.85[f] | .740 | 71.42[e] | .740 | 70.89[e] | .740 | 71.46[e] | .749 |
| pH[c] | 5.80[f] | .037 | 5.74[ef] | .037 | 5.68[e] | .037 | 6.01[g] | .039 |
| Lipid, %[d] | 2.32[f] | .154 | 1.58[e] | .156 | 1.90[ef] | .154 | 2.30[f] | .156 |
| Moisture, %[d] | 73.48 | .163 | 73.74 | .165 | 73.60 | .163 | 73.72 | .165 |

[a]Warner-Bratzler Shear.
[b]Chop location is posterior=2 in, central posterior=7 in, central anterior=12 in, anterior=17 in, measured posterior to anterior; n=82 loins.
[c]Chop location is posterior=4 in, central posterior=9 in, central anterior=14 in, anterior=19 in, measured posterior to anterior; n=40 loins.
[d]Chop location is posterior=3 in, central posterior=8 in, central anterior=13 in, anterior=18 in, measured posterior to anterior; n=40 loins.
[e,f,g]Means in the same row without a common superscript letter differ (P<.05).

**Robert Beckley, Farrowing House and Nursery Manager.**

# EFFECTS OF DIET COMPLEXITY AND PROCESSING METHOD ON GROWTH PERFORMANCE AND NUTRIENT DIGESTIBILITY IN NURSERY PIGS

***S. L. Traylor [1], K. C. Behnke [1], J. D. Hancock, R. H. Hines, J. M. DeRouchey, S. L. Johnston, and P. Sorrell***

## Summary

A complex diet formulation resulted in greater digestibility of nutrients and a trend for greater ADG for d 0 to 14 of the experiment. However, for d 14 to 28 and overall (d 0 to 28), diet complexity did not affect growth performance. In contrast, pelleting improved essentially every response criterion especially in simple diets. Expander conditioning before pelleting increased overall digestibility of nutrients and of F/G compared to standard conditioning, but again, the response was most pronounced with the simple diet formulations.

(Key Words: Expander, Pellets, Nursery Pigs.)

## Introduction

Expander conditioning is a relatively new processing technology to the U. S. feed manufacturing industry. Very few experiments have been conducted to evaluate the effects of expander processing on nutritional value of corn-soybean meal-based diets. The studies that exist show little consensus about the effects of expanding complex nursery diets. Thus, we designed an experiment to determine the effects of diet formulation and processing method on growth performance and nutrient digestibility in nursery pigs.

## Procedures

A total of 150 weanling pigs (10 d post-weaning and initial wt of 22.7 lb) were blocked by weight and sorted by sex and ancestry to pens. There were five pigs per pen (4 ft × 5 ft) and five pens per treatment. Treatments were arranged in a 2 × 3 factorial with the main effects of diet complexity and processing method. The corn-soybean meal-based simple (1.5% fish meal) and complex (3.0% fish meal and 20% whey) formulations had 1.45% lysine, .9% Ca, .8% P, and 1.50 Mcal of ME/lb (Table 1). The diets were fed as a meal control, standard-conditioned pellets, and expander-conditioned pellets.

The pigs were housed in an environmentally controlled nursery room and were allowed ad libitum access to feed and water. Pigs and feeders were recorded on d 0, 14, and 28 to allow calculation of ADG, ADFI, and F/G. Fecal samples were collected at 6 p.m. on d 16 and 6:00 a.m. on d 17. Fecal samples from each pen were dried, pooled within pen; and analyzed for DM, N, GE, and Cr concentrations to allow calculation of apparent nutrient digestibilities using the indirect ratio method.

The mash feed for both the standard and expander pellets was steam conditioned to 175°F and 145°F for the simple and complex formulations, respectively. The stan-dard-conditioned pellets were prepared with a 30 horsepower (California Pellet Mill 1000 Series, Master H.D. Model®) pellet mill. The expanded diets were conditioned, expanded, and then pelleted using the same pellet mill and die specifications listed above. The expander (Amandus-Kahl, Model OE15.2) cone pressure was computer controlled such that the expander energy input (i.e., net energy) was held constant at 12

[1]Department of Grain Science and Industry.

kWh/t for both diets formulations. The pellet mill and expander motors were equipped with a recording volt-amp meter to allow calculation of electrical energy consumption for both pelleting and expanding. Net energy consumption was calculated as the difference between total energy consumption during processing and idle energy consumption.

Pellet samples were collected immediately after exiting the pellet die and cooled with ambient air. The cooled pellets were then analyzed for pellet durability index (PDI) using standard PDI procedures and by modifying the standard procedure by adding five (1/2") hexagonal nuts to the pellet sample before tumbling.

The data were analyzed as a randomized complete block design with pen as the experimental unit. Treatment comparisons were made by using orthogonal contrasts: 1) diet formulation; 2) meal vs pellets; 3) standard conditioning vs expander conditioning; 4) diet formulation × meal vs pellets; and 5) diet formulation × standard conditioning vs expander conditioning.

## Results and Discussion

Net energy consumptions for the expander were 11.9 and 12.1 kWh/t for the simple and complex diet formulations, respectively (Table 2). However, energy required by the pellet mill was greater for the complex formulations than the simple formulations. This resulted from whey in the complex formulation causing increased adhesion of the pellet to the pellet die surface. Thus, this resistance increased the force required to push the pellets through the die. The PDI was greater for the complex diets than for the simple diets, and expander-conditioned pellets had greater PDI than the standard-conditioned pellets.

For d 0 to 14 of the growth assay, pigs fed the complex diets had 5% greater ADG ($P<.09$) and 3% better F/G than pigs fed the simple diets (Table 3). Pigs fed the pelleted diets had 7% greater ADG ($P<.04$) and 14% better F/G ($P<.001$), and 2.7, 2.7 and 3.5% greater digestibilities of DM, N, and GE than pigs fed the meal controls. For the overall period, rates and efficiencies of gain were not affected by diet formulation ($P>.12$), but ADG tended to be greater ($P<.08$) and F/G was better ($P<.01$) when pigs were fed pelleted diets. However, the effects of diet complexity and pelleting were not always independent for ADG; pelleting increased ADG only for pigs fed the simple diet formulations.

Overall (d 0 to 28) pigs fed the expanded pellets tended to have reduced ADG ($P<.07$) but better F/G ($P<.06$) and digestibilities of DM, N, and GE compared to pigs fed the standard-conditioned pellets.

In conclusion, our data suggest that pigs fed complex diets that were processed by expansion tended to have poorer ADG. However, pelleting improved efficiency of gain, and expander conditioning was beneficial for processing simple diets.

**Table 1. Diet Composition[a]**

| | Formulation | |
|---|---|---|
| Item | Simple | Complex |
| Corn | 61.56 | 45.98 |
| Soybean meal (46.5%CP) | 28.34 | 23.62 |
| Whey powder | -- | 20.00 |
| Soybean oil | 2.76 | 3.04 |
| Fish meal | 1.50 | 3.00 |
| Monocalcium phosphate | 1.90 | 1.33 |
| Limestone | 1.00 | .67 |
| Salt | .50 | .10 |
| Lysine-HCl | .47 | .37 |
| Vit/Min/AA/Ab[b] | 1.77 | 1.69 |
| Chromic oxide[c] | .20 | .20 |
| Total | 100.00 | 100.00 |

[a]Formulated to 1.45% lysine, .9 % Ca, .8 % P, and 1.50 Mcal of ME/lb.
[b]Provided 50 g/ton of carbadox.
[c]Used as an indigestible marker.

**Table 2. Effects of Diet Complexity on Processing Characteristics**

| | Simple | | Complex | |
|---|---|---|---|---|
| Item | Standard | Expander | Standard | Expander |
| Pelleting durability,% | | | | |
| Standard | 62.7 | 94.3 | 91.3 | 90.5 |
| Modified | 42.5 | 90.4 | 86.0 | 85.0 |
| Energy consumption, kWh/t | | | | |
| Expander total | - | 34.6 | - | 35.0 |
| Expander specific | - | 11.9 | - | 12.1 |
| Pellet mill total | 6.8 | 9.4 | 7.8 | 9.4 |
| Overall total | 6.8 | 44.0 | 7.8 | 44.4 |

**Table 3. Effects of Diet Complexity and Processing Method on Growth Performance and Nutrient Digestibility in Nursery Pigs[a]**

| | Simple | | | Complex | | | | Contrasts[b] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Meal | Std | Exp | Meal | Std | Exp | SE | 1 | 2 | 3 | 4 | 5 |
| Growth performance | | | | | | | | | | | | |
| Day 0 to 14 | | | | | | | | | | | | |
| ADG, lb | .96 | 1.12 | 1.13 | 1.14 | 1.16 | 1.08 | .04 | .09 | .04 | --[d] | .02 | -- |
| ADFI, lb | 1.44 | 1.46 | 1.39 | 1.62 | 1.44 | 1.38 | .04 | .14 | .004 | .08 | .009 | -- |
| F/G | 1.50 | 1.30 | 1.23 | 1.42 | 1.24 | 1.28 | .03 | -- | .001 | -- | -- | .11 |
| Day 14 to 28 | | | | | | | | | | | | |
| ADG, lb | 1.51 | 1.64 | 1.59 | 1.65 | 1.59 | 1.52 | .04 | -- | -- | .13 | .007 | -- |
| ADFI, lb | 2.19 | 2.30 | 2.09 | 2.47 | 2.21 | 1.98 | .07 | -- | .006 | .004 | .005 | -- |
| F/G | 1.45 | 1.40 | 1.31 | 1.50 | 1.39 | 1.30 | .04 | -- | .005 | .05 | -- | -- |
| Day 0 to 28 | | | | | | | | | | | | |
| ADG, lb | 1.23 | 1.38 | 1.36 | 1.39 | 1.38 | 1.30 | .03 | .12 | .08 | .07 | .003 | -- |
| ADFI, lb | 1.81 | 1.88 | 1.74 | 2.04 | 1.83 | 1.68 | .04 | -- | .001 | .003 | .001 | -- |
| F/G | 1.47 | 1.36 | 1.28 | 1.47 | 1.33 | 1.29 | .03 | -- | .001 | .06 | -- | -- |
| Nutrient digestibility (d 16), % | | | | | | | | | | | | |
| DM | 81.8 | 83.3 | 86.1 | 84.5 | 86.9 | 87.2 | .5 | .001 | .001 | .02 | -- | .04 |
| N | 78.5 | 79.3 | 82.8 | 79.2 | 81.5 | 83.0 | .7 | .06 | .001 | .001 | -- | .14 |
| GE | 81.9 | 83.5 | 87.6 | 83.9 | 87.4 | 88.4 | .5 | .001 | .001 | .001 | -- | .02 |
| Diet DE, kcal/lb[c] | 1,503 | 1,541 | 1,624 | 1,517 | 1,601 | 1,618 | 10 | .02 | .001 | .001 | -- | .004 |

[a]A total of 150 weanling pigs (five pigs per pen and five pens per treatment) with an avg initial wt of 22.7 lb.

[b]Contrasts were: 1) diet formulation; 2) meal vs pellets; 3) standard conditioning vs expander conditioning; 4) diet formulation × meal vs pellets; and 5) diet formulation × standard conditioning vs expander conditioning.

[c]Calculated as percentage GE digestibility × GE of the diet in Mcal/kg.

[d]Dashes indicate P>.15.

# EFFECTS OF CONDITIONERS (STANDARD, LONG-TERM, AND EXPANDER) ON PELLET QUALITY AND GROWTH PERFORMANCE IN NURSERY PIGS

*S. L. Johnston, R. H. Hines, J. D. Hancock, K. C. Behnke [1], C. A. Maloney, S. L. Traylor [1], and S. P. Sorrell*

## Summary

In our first experiment, digestibilities for DM, N, and GE were greater and F/G was better for pigs fed pelleted diets than for pigs fed meal diets. However, we observed no advantages in ADG or F/G with long-term conditioning. In a second experiment, pelleting once again improved nutrient digestibility and F/G. Expander conditioning improved digestibilities of DM, N, and GE but not growth performance compared to standard conditioning.

(Key Words: Nursery Pigs, Pelleting, Expander Conditioning.)

## Introduction

Previous research from our laboratory indicated that pelleting improved rate and efficiency of gain in growing pigs. Long-term and expander conditioning have been used to increase pellet quality, but very little research has been done to compare the effects of these conditioning technologies on animal performance. Thus, the experiments reported herein were designed to determine the effects of standard, long-term, and expander conditioning on growth performance and nutrient digestibility in weanling pigs.

## Procedures

In Exp. 1, 180 weanling pigs (average age of 21 d) were blocked by weight and allotted to pens based on sex and ancestry. There were six pigs per pen and six pens per treatment. The pigs were housed in an environmentally controlled building and allowed ad libitum access to feed and water.

The pigs were offered the experimental Phase III nursery diets (Table 1) starting on d 16 postweaning (average initial BW of 25.8 lb) and fed for an additional 28 d. Treatments were: 1) meal control; 2) stand-ard-conditioned mash; 3) standard-conditioned pellets; 4) long-term-conditioned mash; and 5) long-term-conditioned pellets. Chromic oxide was added at .2% to the diets, and feces were collected by rectal message for analyses of DM, N, GE, and Cr concentrations.

**Table 1. Composition of the Basal Nursery Diet[a]**

| Ingredient | % |
|---|---|
| Corn | 54.55 |
| Soybean meal (46.5% CP) | 37.98 |
| Lysine-HCL | .03 |
| DL-Methionine | .14 |
| Monocalcium phosphate | 1.62 |
| Limestone | .89 |
| Soy oil | 3.00 |
| Salt | .30 |
| Vitamin premix[b] | .25 |
| Trace mineral premix | .15 |
| Copper sulfate | .09 |
| Antibiotic[c] | 1.00 |
| Total | 100.00 |

[a]Formulated to 1.30% lys, .80% Ca, and .70% P.
[b]Expanded diets were fortified at 125% of the vitamins used in the basal diet.
[c]Provided 50 g/ ton carbadox.

Standard diets were steam conditioned to 175°F (California Pellet Mill® conditioner)

[1]Department of Grain Science and Industry.

with a retention time of 10 seconds. Long-term conditioning was done in a two-pass conditioner (California Pellet Mill®) with a temperature of 175°F and a retention time of 2 min and 40 seconds.

The diets were pelleted through a 1.5-inch-thick die with 5/32-inch-diameter openings. Pellet durability index (PDI) was determined by tumbling 500 g of cooled pellets in a rotating metal box for 10 min. The percentage of pellets that would not pass through a No. 6 screen was used as the PDI value. Starch damage (i.e., the combined effects of gelatinization and shear) for all diets was determined using a glucoamylase procedure.

Pigs and feeders were weighed at the beginning and end of the experiment to allow calculation of ADG, ADFI, and F/G. The data were analyzed using the GLM procedures of SAS. Contrasts were: 1) unconditioned meal vs all other treatments; 2) mash vs pellets; 3) standard conditioning vs long-term conditioning; and 4) mash vs pellets × standard conditioning vs long-term conditioning. Pen was the experimental unit.

In Exp. 2, 180 weanling pigs (average initial age of 21 d) were blocked by weight and allotted to pens based on sex and ancestry. Facilities management and data collection were the same as for Exp. 1. The Phase III treatments were started at d 14 after weaning (average initial BW of 22.9 lb) and fed for an additional 28 d. Treatments were: 1) meal control; 2) standard-conditioned mash; 3) standard-conditioned pellets; 4) expander-conditioned mash; and 5) expander-conditioned pellets. The data were analyzed as in Exp. 1 with the contrasts: 1) unconditioned meal vs all other treatments; 2) mash vs pellets; 3) standard conditioning vs expander conditioning; and 4) mash vs pellets × standard conditioning vs expander conditioning. Pen was the experimental unit.

## Results and Discussion

In Exp. 1, the PDI was increased by 46% with long-term conditioning (Table 2). This improvement is consistent with the greater starch damage (making the starch more sticky) for the long-term processing versus standard steam conditioning. Growth performance of the pigs (Table 3) indicated that pelleting improved F/G by 15% (P<.004) compared to conditioned mash. Also, DE of the diet and digestibilities of DM, N, and GE were increased by pelletizing (P<.009). However, we observed no advantages in digestibilities of nutrients or growth performance for pigs fed long-term versus standard conditioning treatments (P>.24). In Exp. 2, pelleting increased ADG by 5% (P<.08) and improved F/G by 12% (P<.001) compared to the conditioned mash diets. Expander conditioning improved PDI by 23%. Also, digestibility of nutrients was greater (P<.05) with expander processing versus standard conditioning. However, growth performance generally was not affected by type of conditioning.

In conclusion, digestibility of nutrients and F/G were improved with pelleting. Pellet durability index and digestibility of nutrients were improved with long-term and expander conditioning, but growth performance was not affected.

**Table 2. Processing Characteristics of Nursery Diets**

| | Experiment 1 | | Experiment 2 | |
|---|---|---|---|---|
| Item | Standard pellet | Long-term pellet | Standard pellet | Expander pellet |
| Pellet durability index, % | | | | |
| Standard[a] | 69.5 | 92.0 | 70.6 | 87.0 |
| Modified[b] | 56.5 | 90.0 | 57.8 | 71.0 |
| Starch damage, %[c] | 34.9 | 38.1 | 34.9 | 40.5 |

[a]Am. Soc. Agric. Engin. procedure. [b]Am. Soc. Agric. Engin. procedure modified with the addition of five ½ inch hexagonal nuts prior to tumbling. [c]For Exp. 1, starch damages were 26.1% for the meal control, 25.0% for standard-conditioned mash, and 37.2% for the long-term-conditioned mash. For Exp. 2, starch damages were 26.1% for the meal control, 25.0% for standard-conditioned mash, and 41.9% for the expander-conditioned mash.

**Table 3. Effects of Standard and Long-Term Conditioning of Feed on Growth Performance and Nutrient Digestibility in Phase-III Nursery Pigs (Exp. 1)[a]**

| | | Standard | | Long-Term | | | Contrasts[b] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | Meal | Mash | Pellet | Mash | Pellet | SE | 1 | 2 | 3 | 4 |
| ADG, lb | 1.24 | 1.24 | 1.31 | 1.30 | 1.26 | .02 | .10 | ---[c] | --- | .02 |
| ADFI, lb | 2.21 | 2.19 | 2.16 | 2.43 | 1.93 | .09 | --- | .006 | --- | .02 |
| F/G | 1.78 | 1.77 | 1.65 | 1.87 | 1.53 | .71 | --- | .004 | --- | .11 |
| Apparent digestiblity, % | | | | | | | | | | |
| GE | 89.9 | 89.1 | 91.2 | 85.6 | 90.4 | .9 | --- | .002 | .04 | .002 |
| N | 89.3 | 87.8 | 90.0 | 86.8 | 88.8 | .7 | --- | .009 | .13 | .009 |
| DM | 89.7 | 88.7 | 90.9 | 87.2 | 90.0 | .4 | --- | .001 | .05 | .001 |
| DE of the diet, kcal/lb | 1,658 | 1,643 | 1,682 | 1,579 | 1,667 | 17 | --- | .002 | .04 | .002 |

[a]One hundred-eighty pigs (avg initial BW of 25.8 lb) were used.
[b]Contrasts were: 1) meal vs others; 2) mash vs pellets; 3) standard vs long-term conditioning; and 4) mash vs pellets × standard vs long-term conditioning.
[c]Dashes indicate P>.15.

**Table 4. Effects of Standard and Expander Conditioning of Feed on Growth Performance and Nutrient Digestibility in Phase-III Nursery Pigs (Exp. 2)[a]**

| | | Standard | | Expander | | | Contrasts[b] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | Meal | Mash | Pellet | Mash | Pellet | SE | 1 | 2 | 3 | 4 |
| ADG, lb | 1.24 | 1.16 | 1.23 | 1.15 | 1.19 | .03 | .09 | .08 | ---[c] | --- |
| ADFI, lb | 2.00 | 1.97 | 1.87 | 1.83 | 1.73 | .05 | .03 | .07 | .09 | --- |
| F/G | 1.61 | 1.70 | 1.52 | 1.59 | 1.45 | .36 | --- | .001 | --- | --- |
| Apparent digestibility, % | | | | | | | | | | |
| GE | 87.2 | 86.0 | 88.4 | 89.1 | 90.2 | .8 | --- | .05 | .008 | .05 |
| N | 85.2 | 83.8 | 85.1 | 86.6 | 88.2 | .9 | --- | .14 | .006 | .14 |
| DM | 86.3 | 85.7 | 87.5 | 88.1 | 89.0 | .6 | .07 | .04 | .003 | .04 |
| DE of the diet, kcal, lb | 1,643 | 1,620 | 1,666 | 1,665 | 1,699 | 15 | --- | .05 | .008 | .05 |

[a]One hundred-eighty pigs (avg initial BW of 22.9 lb) were used.
[b]Contrasts were: 1) meal vs others; 2) mash vs pellets; 3) standard vs expander conditioning; and 4) among mash vs pellets × standard vs expander conditioning.
[c]Dashes indicate P>.15.

# EFFECTS OF EXPANDER CONDITIONING OF CORN- AND SORGHUM-BASED DIETS ON PELLET QUALITY AND PERFORMANCE IN FINISHING PIGS AND LACTATING SOWS[1]

*S. L. Johnston, J. D. Hancock, R. H. Hines, K. C. Behnke[2], G. A. Kennedy[3], C. A. Maloney, S. L. Traylor[2], and S. P. Sorrell*

## Summary

Pellet durability index was similar for sorghum- vs corn-based diets but was greater for expander-conditioned pellets than standard-conditioned pellets. For finishing pigs, ADG, F/G, and carcass measurements were similar for pigs fed sorghum vs corn. Efficiency of gain was 6% better for pigs fed pelleted diets compared to those given meal diets but was similar for pigs fed the conventional- and expander-conditioned diets. For sows, the corn- and sorghum-based diets supported similar litter performance. Our data indicate that sorghum is an excellent feedstuff, comparable to corn, in diets for finishing pigs and sows.

(Key Words: Sorghum, Expander, Pellets, Sows, Finishing Pigs.)

## Introduction

Sorghum grain is a major crop in Kansas. Experiments suggest that relative feeding value for sorghum is at least 95 to 97% that of corn. However, the price of sorghum grain is generally 10% less than that of corn, making sorghum an economical alternative to corn for use in swine diets.

Nutrient digestibility of grain sorghum has been reported to respond more to particle size reduction than corn. However, little research has compared the two energy sources after thermal processing. Therefore, two experiments were designed to compare corn and sorghum as mash, standard-conditioned pellets, and expanded-conditioned pellets in diets for finishing pigs and lactating sows.

## Procedures

A total of 72 (avg initial wt of 128 lb) crossbred barrows (PIC line 326 boars × C15 sows) was blocked by weight, sorted by ancestry, and allotted to pens in an environmentally controlled building. There were two pigs per pen and six pens per treatment. Treatments were: corn-based 1) meal, 2) standard-conditioned pellets, 3) expander-conditioned pellets; and sorghum-based 4) meal, 5) standard-conditioned pellets, and 6) expander-conditioned pellets. In the sorghum- based diets, sorghum replaced corn on a w:w basis (Table 1). The diets were formulated to .9% lysine, .65% Ca, and .55% P. To make up for any loss of potency, vitamins were added to the expanded diets at 1.25 times the amount of the basal diet.

The grain portion of the diets was ground using a hammermill equipped with a screen having 1/8 in. openings. The geometric mean particle sizes ($d_{gw}$) were 572 μm for the corn and 528 μm for the sorghum. The standard pellet diets were preconditioned at 175 °F using a California Pellet Mill® conditioner with a retention time of 10 sec. The expanded diets were preconditioned to a temperature of 175°F and expanded (Aman -

[1]We thank the Kansas Department of Agriculture and the Kansas Sorghum Commission for funding this project.

[2]Department of Grain Science and Industry.

[3]Department of Diagnostic Medicine/Pathobiology.

dus-Kahl) using a cone pressure of 200 psi. Both, standard- and expander-conditioned diets were pelletized in a California Pellet Mill® 1000 series "Master HD" model pellet mill. The die was 1.5 in. thick and had 3/16 in. diameter holes. Electrical energy consumption was measured on the main drive motor for the expander and pellet mill using an amp-volt meter. Pellet durability index (PDI) was measured on the cooled pellets using standard procedures. Briefly, 500 g of cooled pellets were placed in a rotating metal box for 10 min. This procedure also was conducted with five ½ in. hexagonal nuts added to the pellets prior to tumbling.

**Table 1. Compositions of Basal Diets for Finishing[a]**

| Ingredient, % | Corn | Sorghum |
|---|---|---|
| Corn | 79.87 | ---- |
| Sorghum | ---- | 79.87 |
| Soybean meal (46.5% CP) | 15.74 | 15.74 |
| Soy oil | 1.00 | 1.00 |
| Lysine-HCL | .29 | .31 |
| Threonine | .05 | .12 |
| DL-methionine | .05 | .14 |
| Tryptophan | .01 | ---- |
| Monocalcium phosphate | 1.07 | 1.07 |
| Limestone | 1.03 | 1.03 |
| Salt | .30 | .30 |
| Vitamin premix[b] | .15 | .15 |
| Trace mineral premix | .10 | .10 |
| Corn starch | .21 | .04 |
| Antibiotic[c] | .13 | .13 |
| Total | 100.00 | 100.00 |

[a]Diets were formulated to .9% lys, .65% Ca, and .55% P.
[b]Expanded diets were fortified (at the expense of corn starch) to 1.25 times the vitamins of the basal diet.
[c]Provided 50 mg of tylosin per lb of diet.

The 5-ft × 5-ft pens were equipped with a one-hole self-feeder and nipple waterer to allow ad libitum consumption of food and water. The pigs and feeders were weighed at initiation, d 32, and conclusion of the growth assay to allow calculation of ADG, ADFI, and F/G. Chromic oxide was added to the feed as an indigestible marker, and apparent digestibilities of DM and N were determined. The pigs were slaughtered on d 50 (average final BW of 243 lb). Hot carcass weights were taken to allow calculation of dressing percentage. Last rib fat depth was measured at the midline on both sides of the split carcass and averaged. Stomachs were collected and scored for keratinization: 0=normal; 1=mild keratinization; 2=moderate keratinization; and 3=severe keratinization; and for ulceration: 0=normal; 1=mild ulceration; 2=moderate ulceration; and 3=severe ulceration.

Growth data were analyzed using the GLM procedure of SAS. Contrasts were: 1) corn vs sorghum; 2) meal vs pellets; 3) standard-conditioned pellets vs expander-conditioned pellets; 4) corn vs sorghum × meal vs pellets; and 5) corn vs sorghum × standard-conditioned pellets vs expanded-conditioned pellets. Stomach morphology changes were analyzed using the Cochran-Mantel-Haenszel procedure of SAS.

For the sow experiment, 168 animals (PIC line C15 with 1 to 4 parities) were used in a 21-d lactation experiment. At d 110 of gestation, the sows were washed and moved into an environmentally controlled farrowing facility. Treatment began on d 110 to acclimate the sows to the feed prior to farrowing. Diets were corn- and sorghum-based (Table 2) and formulated to 1.0% lysine, .9% Ca, and .8% P. Treatments and feed processing were the same as for the finishing experiment, except the pellet mill die had an opening of 5/16 in.

The sows were scanned ultrasonically for backfat and weighed at farrowing and weaning. Litters size was equalized by d 2 of lactation. Piglet weights were recorded at farrowing and weaning.

The sows had ad libitum access to water and were fed four times daily to ensure ad libitum access to feed while minimizing feed wastage. The feed had .2% chromic oxide added, and grab samples of feces were collected on d 18 from each sow. Feed and feces were analyzed for DM, N, GE, and Cr, and apparent digestibilities were calculated. At weaning, sows were moved to an environ-

mentally controlled breeding barn and serviced.

**Table 2. Compositions of Basal Diets for Lactation[a]**

| Ingredient, % | Corn | Sorghum |
|---|---|---|
| Corn | 64.54 | — |
| Sorghum | — | 64.54 |
| Soybean meal (46.5% CP) | 27.01 | 27.01 |
| Corn gluten meal (60% CP) | 2.50 | 2.50 |
| Soy oil | 1.00 | 1.00 |
| Monocalcium phosphate | 2.06 | 2.06 |
| Limestone | 1.14 | 1.14 |
| Salt | .50 | .50 |
| Vitamin premix[b] | .25 | .25 |
| Sow premix[b] | .25 | .25 |
| Trace mineral premix | .15 | .15 |
| Lysine-HCL | — | .02 |
| Corn starch | .30 | .28 |
| Antibiotic[c] | .10 | .10 |
| Chromic oxide[d] | .20 | .20 |
| Total | 100.00 | 100.00 |

[a]Diets were formulated to 1.0% lys, .9% Ca, and .8% P.
[b]Expanded diets were fortified (at the expense of corn starch) to 125% of the vitamins of the basal diet.
[c]Supplied 50 mg chlortetracycline per lb of diet.
[d]Indigestible marker.

The data were analyzed using the GLM procedures of SAS with the same contrasts as used for the finishing experiment. Sow was the experimental unit.

## Results and Discussion

The PDIs (Table 3) were 77.6% (average of standard and modified procedures) for the standard corn pellets and 78.0% for the standard sorghum pellets. The expanded corn pellets had a PDI of 96.6%, whereas the PDI for the expanded sorghum pellets was 91.3%.

These data suggest that the conditions used with standard steam processing were effective for both corn- and sorghum-based diets. However, with expander processing, the PDIs were greater for corn-based diets than for the sorghum-based diets. Thus, either PDIs in sorghum-based diets simply will not respond as much to expander processing, or the expander conditions were optimized for the corn-based but not the sorghum-based diets. No differences (P>.15) in ADG, ADFI, F/G, or digestibility of DM occurred among pigs fed the corn and sorghum diets (Table 4). However, DE and digestibilities of N were greater in corn- vs sorghum-based diets (P<.001). Pelleting improved F/G by 6% (P<.04) and DE and apparent digestibilities of DM, N, and GE (P<.001). Expander conditioning increased (P<.003) apparent digestibilities of DM and GE but did not improve ADG or F/G compared to standard steam conditioning (P>.12). Treatment had no effect on dressing percentage (P>.12) or last rib fat depth (P>.15).

Pigs fed grain sorghum had greater keratinization (P<.04) but no greater severity of ulcers (P>.5) compared to pigs fed corn (Table 5). Pelleting the diets increased both keratinization and ulceration (P<.002), but no difference occurred between the standard pellets and the expander pellets (P>.4).

For the sow experiment, PDIs (Table 6) were 60.8% (average of standard and modified procedures) for the standard corn pellets and 66.0% for the standard sorghum pellets. The expanded corn pellets had a PDI of 90.2%, whereas the PDI for the expanded sorghum pellets was 86.3%. Thus, with the finishing diet used in Exp. 1, the corn-based diet responded more to expander processing than the sorghum-based diet.

Weight loss (Table 7) was not different (P>.15) for sows fed the corn- and sorghum-based diets. Also, no differences in the number of pigs weaned, survivability of the pigs, digestibility of DM, or digestibility of GE occurred for sows fed the corn- vs sorghum-based diets (P>.15). However, it is noteworthy that final litter weights for sows fed the sorghum-based diet in meal form were numerically 3% lower than those of the sows fed the corn-based meal treatment. This difference disappeared with pelleting.

Pelleting improved apparent digestibilities of DM, N, and GE (P<.001), and digestibilities of N and GE in the sorghum-based diets increased more with pelleting than

digestibilities in the corn-based diet (corn vs sorghum × mash vs pellets interaction, P<.04). Expanding prior to pelleting improved (P<.05) DE and digestibility of GE of the diet and tended (P<.08) to improve apparent digestibility of N. Finally, the percentage of sows that returned to estrus and the length of time to return were similar for all treatments (P>.2).

In conclusion, few differences occurred in performance data among finishing pigs and sows fed corn versus sorghum. This is probably because of advances in grain sorghum hybrids and response of grain sorghum to advanced feed processing (e.g., grinding to less than 600 μm). Pelleting improved F/G in the finishing experiment by 6% for both sorghum- and corn-based diets. Thus sorghum, when properly processed, can be used to decrease diet costs, while maintaining a high level of animal performance.

**Table 3. Effects of Standard and Expander Conditionings on Corn- and Sorghum-Based Finishing Diets**

| | Corn | | Sorghum | |
|---|---|---|---|---|
| Item | Standard pellets | Expanded pellets | Standard pellets | Expanded pellets |
| Pellet production rate, lb/h | 3,108 | 2,504 | 3,186 | 2,518 |
| Electrical energy consumption, kWh/t | | | | |
| Pellet mill | | | | |
| Gross | 8.6 | 8.7 | 9.1 | 10.4 |
| Specific | 3.3 | 2.1 | 3.8 | 3.8 |
| Expander | | | | |
| Gross | --- | 32.1 | --- | 27.2 |
| Specific | --- | 12.6 | --- | 7.6 |
| Pellet durability index, % | | | | |
| Standard[a] | 83.0 | 96.6 | 83.7 | 93.4 |
| Modified[b] | 72.2 | 96.2 | 72.3 | 89.2 |
| Starch damage, %[c] | 35.1 | 50.0 | 32.8 | 46.8 |

[a]Am. Soc. Agric. Engin. method (1987).
[b]Am. Soc. Agric. Engin. method (1987) with the addition of five (½ in.) hexagonal nuts prior to tumbling.
[c]Mash values were 29.8 for corn- and 24.2 for sorghum-based diets and estimates of total starch damage resulting from gelatinization and shear.

**Table 4. Effects of Corn- and Sorghum-Based Diets Fed in Three Forms on Performance of Finishing Pigs[a]**

| | Corn | | | Sorghum | | | | Contrasts[b] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Meal | Standard pellets | Expanded pellets | Meal | Standard pellets | Expanded pellets | SE | 1 | 2 | 3 | 4 | 5 |
| Overall (d 0 to 50) | | | | | | | | | | | | |
| ADG, lb | 2.31 | 2.39 | 2.37 | 2.45 | 2.30 | 2.44 | .07 | ---[c] | --- | --- | .15 | --- |
| ADFI, lb | 6.87 | 6.96 | 6.47 | 7.31 | 6.55 | 6.74 | .16 | --- | .005 | --- | .08 | .04 |
| F/G | 2.97 | 2.91 | 2.73 | 2.98 | 2.85 | 2.76 | .08 | --- | .04 | .12 | --- | --- |
| Apparent nutrient digestibility, % | | | | | | | | | | | | |
| DM | 90.5 | 91.4 | 92.4 | 90.8 | 91.8 | 92.9 | .3 | --- | .001 | .003 | --- | --- |
| N | 86.9 | 89.0 | 90.1 | 84.3 | 86.7 | 87.8 | .8 | .001 | .001 | --- | --- | --- |
| GE | 90.5 | 92.2 | 93.3 | 90.5 | 92.3 | 93.4 | .3 | --- | .001 | .003 | --- | --- |
| DE of the diet, kcal/lb | 1,672 | 1,705 | 1,724 | 1,647 | 1,678 | 1,698 | 6 | .001 | .001 | .003 | --- | --- |
| Dressing percentage | 73.5 | 73.7 | 73.0 | 72.5 | 73.4 | 72.6 | .5 | --- | --- | .12 | --- | --- |
| LRFD, in | 1.14 | 1.15 | 1.12 | 1.16 | 1.11 | 1.15 | .05 | --- | --- | --- | --- | --- |

[a]A total of 71pigs (avg initial wt of 128 lb) with two pigs/pen and six pens/treatment.

[b]Contrasts were: 1) corn vs sorghum; 2) meal vs pellets; 3) standard pellets vs expanded pellets; 4) corn vs sorghum × mash vs pellets; and 5) corn vs sorghum × standard pellets vs expanded pellets.

[c]Dashes indicate P>.15.

**Table 5. Effects of Corn- and Sorghum-Based Diets Fed in Three Forms on Stomach Lesions in Finishing Pigs**

| | Corn | | | Sorghum | | | | Contrasts[a] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Meal | Standard pellets | Expanded pellets | Meal | Standard pellets | Expanded pellets | SE | 1 | 2 | 3 | 4 | 5 |
| Stomach keratinization | | | | | | | | | | | | |
| Total observations | 12 | 11 | 12 | 12 | 11 | 12 | | | | | | |
| Normal | 7 | 4 | 1 | 5 | 0 | 2 | | | | | | |
| Mild | 4 | 4 | 7 | 6 | 2 | 5 | | | | | | |
| Moderate | 1 | 2 | 4 | 1 | 8 | 4 | | | | | | |
| Severe | 0 | 1 | 0 | 0 | 1 | 1 | | | | | | |
| Mean score | .5 | 1.0 | 1.3 | .7 | 1.9 | 1.3 | .3 | .04 | .001 | ---[b] | --- | .08 |
| Stomach ulcerations | | | | | | | | | | | | |
| Total observation | 12 | 12 | 12 | 12 | 11 | 12 | | | | | | |
| Normal | 12 | 8 | 6 | 12 | 7 | 8 | | | | | | |
| Mild | 0 | 0 | 5 | 0 | 2 | 1 | | | | | | |
| Moderate | 0 | 0 | 1 | 0 | 2 | 2 | | | | | | |
| Severe | 0 | 4 | 0 | 0 | 0 | 1 | | | | | | |
| Mean score | 0 | 1.0 | .6 | 0 | .6 | .7 | .3 | --- | .002 | --- | --- | --- |

[a]Contrasts were: 1) corn vs sorghum; 2) meal vs pellets; 3) standard pellets vs expanded pellets; 4) corn vs sorghum × mash vs pellets; and 5) corn vs sorghum × standard pellets vs expanded pellets.
[b]Dashes indicate P>.15.

**Table 6. Effects of Standard and Expander Conditioning on Corn- and Sorghum-Based Lactation Diets**

| | Corn | | Sorghum | |
|---|---|---|---|---|
| Item | Standard pellets | Expanded pellets | Standard pellets | Expanded Pellets |
| Pellet production rate, lb/h | 4,098 | 2,427 | 2,363 | 2,549 |
| Electrical energy consumption, kWh/t | | | | |
| Pellet mill | | | | |
| Gross | 6.5 | 8.3 | 6.9 | 8.7 |
| Specific | 2.7 | 2.0 | 3.0 | 2.7 |
| Expander | | | | |
| Gross | --- | 29.0 | --- | 28.0 |
| Specific | --- | 8.4 | --- | 8.3 |
| Pellet durability index, % | | | | |
| Standard[a] | 65.7 | 91.4 | 71.7 | 90.4 |
| Modified[b] | 55.8 | 89.0 | 60.2 | 88.8 |
| Starch damage, %[c] | 35.4 | 45.8 | 34.0 | 47.5 |

[a]Am. Soc. Agric. Engin. method (1987).

[b]Am. Sco. Agric. Engin. method (1987) with the addition of five (1/2 in.) hexagonal nuts prior to tumbling.

[c]Mash values were 25.5 for the corn- and 27.1 for sorghum-based diets and the values are estimates of total starch damage resulting from gelatinization and shear.

**Table 7. Effects of Corn and Sorghum-Based Lactation Diets Fed in Three Forms on Sow and Litter Performance[a]**

| | Corn | | | Sorghum | | | | Contrasts[b] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Meal | Standard pellet | Expanded pellet | Meal | Standard pellet | Expanded pellet | SE | 1 | 2 | 3 | 4 | 5 |
| Sow BW at farrowing, lb | 435.4 | 427.0 | 433.0 | 438.3 | 425.5 | 437.6 | 13.9 | ---- | ---- | ---- | ---- | ---- |
| Sow body weight change, lb | 5.8 | 16.5 | 3.5 | 9.4 | 11.0 | 16.3 | 6.6 | ---- | .13 | ---- | ---- | .005 |
| ADFI, lb | 13.0 | 13.4 | 13.2 | 13.3 | 13.5 | 14.0 | .1 | .08 | ---- | ---- | ---- | ---- |
| Litter performance | | | | | | | | | | | | |
| Initial pigs/litter | 11.4 | 11.6 | 11.5 | 11.6 | 11.5 | 11.6 | .4 | ---- | ---- | ---- | ---- | ---- |
| Pigs weaned/litter | 10.6 | 10.5 | 10.5 | 10.5 | 10.6 | 10.6 | .4 | ---- | ---- | ---- | ---- | ---- |
| Survivability, % | 93.0 | 90.5 | 91.3 | 90.5 | 92.2 | 91.4 | .1 | ---- | ---- | ---- | ---- | ---- |
| Litter weight, lb | | | | | | | | | | | | |
| Initial weight | 37.0 | 37.9 | 37.9 | 37.5 | 37.7 | 38.4 | 2.2 | ---- | ---- | ---- | ---- | ---- |
| Weaning | 134.0 | 128.1 | 135.1 | 131.9 | 135.4 | 138.3 | 7.9 | ---- | ---- | ---- | ---- | ---- |
| Weight gain | 97.0 | 90.2 | 97.2 | 94.4 | 97.7 | 99.9 | 7.3 | ---- | ---- | ---- | ---- | ---- |
| Return to estrus, %[c] | 76.9 | 82.8 | 76.9 | 87.1 | 85.7 | 71.4 | 16.0 | ---- | ---- | ---- | ---- | ---- |
| Days to estrus[d] | 5.0 | 5.1 | 4.5 | 4.5 | 5.3 | 4.9 | .1 | ---- | ---- | ---- | ---- | ---- |
| Apparent nutrient digestibility, % | | | | | | | | | | | | |
| DM | 85.5 | 87.1 | 87.7 | 85.4 | 87.0 | 87.2 | .4 | ---- | .001 | ---- | ---- | ---- |
| N | 89.1 | 89.2 | 91.0 | 84.9 | 87.7 | 88.1 | .8 | .001 | .001 | .08 | .04 | ---- |
| GE | 88.3 | 88.9 | 90.6 | 86.5 | 89.6 | 90.1 | .5 | ---- | .001 | .05 | .008 | .13 |
| DE of the diet, kcal/lb | 1,568 | 1,574 | 1,608 | 1,524 | 1,583 | 1,587 | 9 | .004 | .001 | .05 | .008 | .13 |

[a]One hundred sixty-eight sows with 1 to 4 parities.

[b]Contrasts were: 1) corn vs sorghum; 2) meal vs pellets; 3) standard pellets vs expanded pellets; 4) corn vs sorghum × mash vs pellets; and 5) corn vs sorghum × standard pellets vs expanded pellets.

[c]Percentage of sows returning to estrus within 30 d of weaning.

[d]For sows returning to estrus within 30 d of weaning.

*Swine Day 1998*

# EFFECTS OF EXPANDED WHOLE SOYBEANS ON GROWTH PERFORMANCE AND NUTRIENT DIGESTIBILITY IN NURSERY PIGS

***H. Cao, J. D. Hancock, R. H. Hines, K. C. Behnke [1], J. M. Jiang, J. S. Park, J. R. Froetschner, and C. A. Maloney***

## Summary

As expected, ADG, ADFI, F/G, and digestibility of DM and N were improved in nursery pigs when cone pressure was increased during dry and moist expanding of whole soybeans. These response were quadratic for the most part, such that 1,000 psi was optimal with dry expanding and 700 to 800 psi was optimal with moist expanding.

(Key Words: Expander, Soybeans, Nursery Pigs.)

## Introduction

In just the past years, expander processing has become popular for preparing complete poultry feeds. During expanding, heat changes the physical/chemical structure of starch and protein, making them more tacky. These tacky particles then can be pushed together to make extremely durable pellets. It seemed logical that the same shear heat and shear that improve pellet durability could also serve to inactivate the antinutritional factors in whole soybean seeds. Two experiments were designed to determine the effects of cone pressure (with or without steam preconditioning) during expansion of whole soybeans on growth performance and nutrient digestibility in nursery pigs.

## Procedures

In Exp.1, a total of 150 crossbred pigs was weaned at 21 d and fed a commercial starter diet (Table 1) for 1 wk. At the close of the 1-wk acclimation period, the pigs were blocked by weight and allotted to 25 pens by sex and ancestry (5 pens/trt and 6 pigs/pen) for a 25-d growth assay.

No cone pressure or pressures of 400, 800, 1,000, and 1,200 psi were used during dry expansion (Model OE15.2, Amandus-Kahl, Hamburg, Germany) of whole soybeans. The expanded beans were ground to 550 microns before use in corn-based diets. For d 7 to 21, the diets had 1.05% lysine, .90% Ca, and .80% P, and for d 21 to 32, the diets had .86% lysine, .8% Ca, and .7% P. The lysine concentration was 90% of NRC (1988) recommendation to accentuate differences in growth performance. All other nutrients were in excess of NRC suggestions.

The pigs were housed in an environmentally controlled building with wire-meshed floor. A nipple waterer and a self-feeder provided the pigs with ad libitum access to feed and water. Pigs and feeders were weighed at d 0, 14, and 25. Feces were collected at d 24; dried; and ground for analyses of DM, N, GE, and Cr.

In Exp. 2, a total of 180 crossbred pigs was weaned at 21 d and fed the commercial starter diet for 1 wk. Then they were blocked by weight and allotted to 30 pens by sex and ancestry (6 pens/trt and 6 pigs/pen) for a 24-d growth assay. Soybean treatments were expanding with no cone pressure or pressures of 400, 600, 700, and 800 psi after steam conditioning to 180°F (California Pellet Mill®

[1]Department of Grain Science and Industry.

conditioner) for 10 seconds. The pigs were housed and managed as in Exp. 1.

For both experiments, the growth and digestibility data were analyzed as a randomized completed block design using the GLM procedure of SAS. Pen was the experiment unit, and polynomial regression was used to characterize the slope of the response curve as related to increasing cone pressure.

## Results and Discussion

With both dry and moist expanding, processing energy inputs increased and production rate decreased with increased cone pressures (Table 2). Also, trypsin inhibitor, protein dispersible index, and urease activity were decreased. Previous work has suggested that properly heated soybean products will have a protein dispersible index of 25%, urease activity of .02 to .2, and trypsin inhibitor activity of less than 4 mg/g. With our dry and moist expanding, 1,000 and 700 to 800 psi, respectively, were needed to achieve the targeted laboratory values.

When the soy preparations were fed to pigs (Exp. 1), increasing cone pressure from 0 to 1,200 psi (with dry expanding) improved ADG, ADFI, and F/G and digestibilities of DM, N, and GE (P<.001) (Table 3). However, cubic effect of the cone pressure indicated that when cone pressure increased above 1000 psi, the growth performance fluctuated. Within this range, the optimal response was achieved at 1,000 psi (quadratic effect, P<.03).

For moist expanding (Exp. 2), ADG, ADFI, and F/G and digestibilities of DM and N were improved (P<.001) when cone pressure was increased from 0 to 800 psi (Table 4). However, most of the response was achieved with 600 psi, and the response plateaued at 700 to 800 psi (quadratic effect, P<.001).

In conclusion, expander processing can be used to prepare full-fat soy products. Furthermore, the cone pressure needed to achieve optimal nutritional value can be reduced with moist processing.

**Table 1. Compositions of Basal Diets for Experiments 1 and 2[a]**

| Ingredient, % | d 0 to 7 | d 7 to21 | d 21 to 32 |
|---|---|---|---|
| Corn | 35.82 | 51.81 | 61.05 |
| SBM (47.5% CP) | 24.45 | --- | --- |
| Whole soybeans [b] | --- | 31.60 | 29.35 |
| Dried whey | 20.00 | 10.00 | 5.00 |
| Porcine plasma | 6.00 | 1.00 | --- |
| Fish meal | 1.00 | 1.00 | --- |
| Blood meal | 1.00 | --- | --- |
| Lactose | 5.00 | --- | --- |
| Soy oil | 2.00 | --- | --- |
| Dicalcium phosphate | 1.38 | --- | --- |
| Monocalcium phosphate | --- | 1.62 | 1.49 |
| Limestone | .80 | .98 | 1.04 |
| Salt | .20 | .30 | .35 |
| Threonine | .04 | --- | --- |
| Lysine HCl | .20 | --- | --- |
| DL-methionine | .32 | .03 | .004 |
| Vitamin premix | .25 | .25 | .25 |
| Trace mineral premix | .15 | .15 | .15 |
| Antibiotics [c] | 1.00 | 1.00 | 1.00 |
| Zinc oxide | .39 | .25 | --- |
| Copper sulfate | --- | --- | .07 |
| Chromic oxide [d] | --- | --- | .25 |

[a]Diets for d 0 to 7 were formulated to 1.7% lysine, .9% Ca, and .8% P. Diets for d 7 to 21 were formulated to 1.05% lysine .9% Ca, and .8% P. Diets for d 21 to 32 were formulated to .86% lysine .8% Ca, and .7% P. [b]The expanded whole soybeans were ground to a particle size of 550 microns before use in the diets. [c]Apramycin (150 g/ton) for d 0 to 21and carbadox (50 g/ton) for d 21 to 32. [d]Used as an indigestible marker.

**Table 2. Processing Characteristics of Expanded Soybeans**

| | Cone Pressure, psi | | | | | | |
|---|---|---|---|---|---|---|---|
| Item | 0 | 400 | 600 | 700 | 800 | 1000 | 1200 |
| Dry expanding (Exp.1) | | | | | | | |
| GEI, kwh/ton [a] | 20.9 | 32.8 | -- | -- | 54.4 | 88.2 | 118.9 |
| SEI, kwh/ton [b] | .7 | 10.1 | -- | -- | 34.4 | 48.9 | 72.7 |
| PR, ton/hr [b] | 2.47 | 2.29 | -- | -- | 2.47 | 1.81 | 1.07 |
| Temperature, °F [d] | 82.0 | 112.3 | -- | -- | 190.1 | 236.5 | 312.6 |
| TI, mg/g [e] | 26.4 | 26.6 | -- | -- | 24.8 | 4.6 | 0.4 |
| Urease, ΔpH [f] | 2.24 | 2.24 | -- | -- | 2.24 | 0.18 | 0.02 |
| PDI, % [g] | 86.1 | 83.9 | -- | -- | 61.0 | 14.0 | 9.0 |
| Moist expanding (Exp.2) | | | | | | | |
| GEI, kwh/ton | 19.2 | 37.2 | 38.7 | 43.3 | 47.3 | -- | -- |
| SEI, kwh/ton | .7 | 14.8 | 19.9 | 23.2 | 27.0 | -- | -- |
| PR, ton/hr | 1.35 | 1.11 | 1.32 | 1.24 | 1.20 | -- | -- |
| Temperature, °F | 182.0 | 227.4 | 273.7 | 254.4 | 266.4 | -- | -- |
| TI, mg/g | 29.0 | 13.2 | 3.2 | 3.2 | 2.3 | -- | -- |
| Urease, ΔpH | 2.15 | 1.97 | 1.22 | 1.15 | 0.08 | -- | -- |
| PDI, % | 74.2 | 47.8 | 30.8 | 21.8 | 12.0 | -- | -- |

[a]Gross energy input.
[b]Specific energy input.
[c]Production rate.
[d]Estimated by equation: T (°F) = condition temp + 3.2 × (Specific energy input).
[e]Trypsin inhibitor activity.
[f]Urease activity.
[g]Protein dispersible index.

**Table 3. Effects of Dry-Expanded Whole Soybeans on Growth Performance and Nutrient Digestibility in Nursery Pigs (Exp. 1)[a]**

| | Cone Pressure, psi | | | | | | Contrast [b] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | 0 | 400 | 800 | 1,000 | 1,200 | SE | Lin | Quad | Cub | Quart |
| d 7 to 21 | | | | | | | | | | |
| ADG, lb | .24 | .19 | .26 | .69 | .65 | .05 | .005 | .001 | .001 | .03 |
| ADFI, lb | 1.58 | .92 | .94 | 1.31 | 1.30 | .04 | -- | .001 | .001 | .005 |
| F/G | 4.33 | 4.76 | 3.64 | 1.89 | 2.00 | .09 | .01 | .001 | .001 | -- |
| Overall | | | | | | | | | | |
| ADG, lb | .36 | .31 | .43 | .93 | .83 | .02 | .001 | .001 | .001 | .001 |
| ADFI, lb | 1.28 | 1.25 | 1.24 | 1.76 | 1.72 | .05 | .001 | .001 | .003 | .001 |
| F/G | 3.62 | 3.62 | 2.89 | 1.88 | 2.07 | .02 | .001 | .001 | .001 | .001 |
| Apparent digestibility, % | | | | | | | | | | |
| DM | 76.3 | 72.4 | 75.1 | 79.1 | 80.0 | 1.0 | .001 | .02 | .02 | -- |
| N | 63.6 | 50.0 | 57.9 | 75.2 | 74.4 | 2.0 | .001 | .001 | .001 | -- |
| GE | 75.9. | 71.7 | 75.3 | 79.8 | 80.3 | 1.0 | .001 | .03 | .01 | -- |

[a]A total of 150 nursery pigs was used (6 pigs/pen and 5 pens/trt) with an avg weight of 17 lb.
[b]Dashes indicate P>.15.

**Table 4. Effects of Moist-Expanded Whole Soybeans on Growth Performance and Nutrient Digestibility in Nursery Pigs (Exp. 2)[a]**

| | Cone Pressure, psi | | | | | | Contrast [b] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | 0 | 400 | 600 | 700 | 800 | SE | Lin | Quad | Cub | Quart |
| d 7 to 19 | | | | | | | | | | |
| ADG, lb | .32 | .61 | .73 | .84 | .92 | .04 | .001 | .01 | -- | -- |
| ADFI, lb | .97 | 1.10 | 1.33 | 1.46 | 1.48 | .07 | .001 | -- | -- | -- |
| F/G | 3.04 | 1.60 | 1.84 | 1.74 | 1.65 | .12 | .01 | .06 | .04 | -- |
| Overall | | | | | | | | | | |
| ADG, lb | .37 | .63 | .87 | .88 | .99 | .03 | .001 | .001 | -- | -- |
| ADFI, lb | 1.19 | 1.37 | 1.63 | 1.72 | 1.8 | .06 | .001 | .09 | -- | -- |
| F/G | 3.26 | 2.17 | 1.89 | 1.95 | 1.82 | .01 | .001 | .001 | .001 | -- |
| Apparent digestibility, % | | | | | | | | | | |
| DM | 78.8 | 80.7 | 81.9 | 82.2 | 80.3 | .6 | .001 | .02 | -- | -- |
| N | 62.3 | 70.6 | 75.5 | 76.0 | 76.3 | 1 | .001 | .001 | -- | -- |

[a]A total of 180 nursery pigs was used (6 pigs/pen and 6 pens/trt) with an avg wt of 17 lb.
[b]Dashes indicate P>.15.

# CONDITIONS DURING EXPANDER PROCESSING OF SOYBEAN MEAL AND RAW SOYBEANS AFFECT NUTRIENT DIGESTIBILITY IN FINISHING PIGS [1]

*S. L. Traylor [2], J. D. Hancock, K. C. Behnke [2], R. H. Hines, N. Amornthewaphat [2], S. L. Johnson, and P. Sorrell*

## Summary

Expander processing improved nutrient digestibility in diets with soybean meal and raw soybeans. Furthermore, with 600 psi cone pressure (20 kWh/ton of specific energy input), the diets with raw soybeans had equal or greater digestibility of nutrients compared to the soybean meal-based control diet.

(Key Words: Expander, Soybean, Digestibility, Finishing Pigs.)

## Introduction

Research from our laboratory indicates that extrusion of cereal grains and soybeans improves their feeding value for nursery and(or) finishing pigs. Expander technology is similar to extrusion, with primary benefits of improved pellet quality and feed hygiene. However, this technology probably could be used to inactivate the antinutritional factors found in raw soybean seeds. Thus, we designed an experiment to determine the effects of expander processing on nutrient digestibility in finishing pigs fed a diet with corn-soybean meal and whole soybeans.

## Procedures

A total of 64 pigs was used in the 15-d (three replicates of a 5-d treatment period) digestibility assay. The pigs were blocked by weight and sorted by sex and ancestry. There were eight pigs (average initial BW of 190 lb) in each 6-ft × 16-ft pen. Diets were formulated to .9% lysine, .65% Ca, and .55% P (Table 1). Treatments were corn-soybean meal- and corn-raw soybean-base diets that were processed without pressure and at 200, 400, and 600 psi cone pressure. Feed and water were consumed on an ad libitum basis. Grab samples of feces were collected by rectal massage from at least six of the pigs in a pen at 6:00 p.m. on d 4 and 6:00 a.m. on d 5 of each treatment period. The samples were dried; pooled within pen; and analyzed for DM, N, GE, and Cr concentrations to allow calculation of apparent nutrient digestibilities.

**Table 1. Diet Compositions[a]**

| Ingredient, % | Soybean Meal | Raw Soybeans |
|---|---|---|
| Corn | 75.01 | 72.89 |
| Soybean meal (46.5% CP) | 18.54 | -- |
| Raw soybean | -- | 23.94 |
| Soybean oil | 3.24 | -- |
| Monocalcium phosphate | 1.05 | .95 |
| Limestone | 1.02 | 1.04 |
| Salt | .30 | .30 |
| KSU Vit/Min/AA/Ab[b] | .64 | .68 |
| Chromic oxide[c] | .20 | .20 |

[a]Formulated to .9% lysine, .65% Ca, .55% P, and 1.62 Mcal of DE/lb.
[b]Provided 100g/ton of lysine.
[c]Used as an indigestible marker.

[1]Appreciation is extended to the Kansas State Board of Agriculture and the Kansas Soybean Commission for funding this project.

[2]Department of Grain Science and Industry.

The diets for all experiments were steam conditioned at 160°F; processed through a 100 horsepower expander (Amandus-Kahl, Model OE15.2); and pelleted with a 30 horsepower California Pellet Mill. The pellet mill loaded a 11/2 in. thick die with 3/16 in. diameter openings. Production rate was held constant at .9 ton/h for all treatments. The pellet mill and expander motors were equipped with a volt-amp meter to allow calculation of electrical energy consumption. Specific energy consumption was calculated as the difference between total energy during processing and idle energy consumption. Pellet samples were collected immediately after exiting the pellet die and cooled with ambient air. The cooled pellet samples were analyzed for pellet durability index (PDI) using standard procedures and also using the standard procedures with five (1/2) hexagonal nuts added to the pellet sample before tumbling.

The data were analyzed as a randomized complete design with a 2 × 4 factorial arrangement of treatments. Main effects were soy source (soybean meal and raw soybeans) and cone pressure (0, 200, 400, and 600 psi).

## Results and Discussion

Moisture concentrations in the conditioned mash and cooled pellets and moisture loss with expanding, pelleting, and cooling were similar for the soybean meal- versus whole soybean-based diets (Table 2). Starch damage was less in the soybean diets, especially at the greater cone pressures. The whole soybeans apparently had a lubricating effect during expander processing that decreased the gelatinization and(or) shear of starch.

The soybean meal-based diets were devoid of urease activity as cone pressure was increased from none to 600 psi. Urease activity in the whole soybean diets was decreased from 1.66 to .21. The recommended urease activity for soy products is .02 to .2, so even at 600 psi, urease activity was still fairly high.

Energy required to expand and expand/pellet was more for soybean meal-based diets ($P<.001$) (Table 3). This was especially true at the greater cone pressures (diet × cone pressure quadratic interaction, $P<.001$). Pellet durability index (standard and modified) increased markedly with increasing cone pressure in the soybean meal-based diets, but the PDIs of the soybean-based diets were less responsive to cone pressure (diet × cone pressure, quadratic interaction, $P>.008$).

As for nutritional difference among the treatments, digestibilities of DM, N, and GE were greater ($P<.007$) for the soybean meal treatments. Also, nutritent digestibilities increased with increased cone pressures (linear effects varying from $P<.06$ to $P<.001$). However, the effects of soy source and cone pressure were not independent. Digestibilities of DM, N, and GE were increased only slightly in the soybean meal diets, with maximal digestibilities achieved at 200 to 400 psi (i.e., specific energy inputs of 7 to 18 kWh/ton). In contrast, digestibility of nutrients in the diets with raw whole soybeans increased markedly as cone pressure was increased from none to 600 psi (diet × cone pressure linear effects ranging from $P<.10$ to $P<.001$). Note that even with 600 psi (specific energy input of 20 kWh/ton), nutritional value of the whole soybean diets was still improving. This suggests that even move cone pressure and energy input would be beneficial for diets with raw soybeans.

In conclusion, expander processing improved the nutritional value of corn-soy-diets. This response was most pronounced in diets with raw soybeans. Optimal cone pressure/specific energy inputs were 200 to 400 psi(7 to 18 kWh/ton) for diets with soybean meal and 600 psi (20 kWh/ton) for diets with whole soybeans.

**Table 2. Effects of Cone Pressure on Diet Characteristic and Nutrient Digestibility in Soybean Meal and Raw Soybean Diets[a]**

| | Soybean Meal | | | | Raw Soybeans | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | 0 | 200 | 400 | 600 | 0 | 200 | 400 | 600 | SE |
| Conditioned mash moisture, % | 15.6 | 15.7 | 15.7 | 15.8 | 15.6 | 15.4 | 15.5 | 15.5 | - |
| Pellet moisture, % | 15.3 | 15.1 | 14.6 | 12.8 | 15.4 | 14.9 | 13.9 | 11.7 | - |
| Moisture loss, % | .3 | .6 | 1.1 | 3.0 | .2 | .5 | 1.6 | 3.8 | - |
| Starch damage, % | 26.0 | 33.7 | 46.3 | 66.0 | 20.7 | 41.3 | 37.4 | 39.5 | - |
| Urease activity, pH rise | .00 | .01 | .00 | .00 | 1.66 | .42 | .16 | .21 | - |
| Energy consumption, kWh/ton | | | | | | | | | |
| Expander | | | | | | | | | |
| Specific | .4 | 6.6 | 18.1 | 54.8 | .9 | 8.7 | 14.4 | 19.8 | |
| Total | 26.0 | 32.2 | 43.8 | 80.5 | 26.7 | 34.2 | 39.9 | 45.6 | |
| Pellet mill total | 12.8 | 10.8 | 9.9 | 11.5 | 12.1 | 9.7 | 9.9 | 10.1 | |
| Overall total | 38.8 | 43.0 | 54.7 | 92.0 | 38.8 | 43.9 | 49.8 | 55.7 | |
| Pellet durability index, % | | | | | | | | | |
| Standard | 47.4 | 81.9 | 93.1 | 91.5 | 79.3 | 86.1 | 84.3 | 84.3 | 3.3 |
| Modified | 24.5 | 71.1 | 91.2 | 89.7 | 69.9 | 71.5 | 76.7 | 78.7 | 4.4 |
| Nutrient digestibility, % | | | | | | | | | |
| DM | 81.2 | 83.1 | 82.6 | 81.7 | 78.3 | 78.7 | 80.4 | 82.0 | 1.0 |
| N | 75.8 | 77.4 | 77.1 | 77.8 | 58.1 | 68.8 | 71.1 | 73.8 | 3.0 |
| GE | 81.1 | 84.0 | 84.0 | 83.3 | 75.1 | 77.7 | 80.4 | 82.8 | 1.2 |
| DE of diet, kcal/lb | 1,496 | 1,546 | 1,556 | 1,545 | 1,353 | 1,423 | 1,510 | 1,576 | 21 |

[a]A total of 64 pigs (eight pigs/pen with an average initial BW of 190 lb) and three replicates/treatment.
[b]The ADFI ranged from 6.2 to 7.5 lb/d for the 15-d experiment.

**Table 3. Probability, P <**

| Item | Diet[a] | Lin | Quad | Cubic | Diet × Lin | Diet × Quad | Diet × Cubic |
|---|---|---|---|---|---|---|---|
| Energy consumption, kWh/ton | | | | | | | |
| Expander | | | | | | | |
| Specific | .001 | .001 | .001 | .06 | .001 | .001 | .13 |
| Gross | .001 | .001 | .001 | .07 | .001 | .001 | .12 |
| Pellet mill | .003 | .001 | .001 | - | - | - | .09 |
| Overall | .001 | .001 | .001 | .10 | .001 | .001 | .08 |
| Pellet durability index, % | | | | | | | |
| Standard | .05 | .001 | .001 | - | .001 | .008 | - |
| Modified | .13 | .001 | .002 | - | .001 | .002 | - |
| Nutrient digestibility, % | | | | | | | |
| DM | .007 | .06 | - | - | .10 | - | - |
| N | .001 | .02 | - | - | .04 | - | - |
| GE | .001 | .001 | - | - | .02 | - | - |
| De of diet , kcal/lb | .001 | .001 | - | - | .001 | - | - |

[a]Diets were either soybean meal- or whole soybean-based.
[b]Dash indicates P>.15.

*Swine Day 1998*

# EXPANDER PROCESSING CONDITIONS AFFECT NUTRIENT DIGESTIBILITY IN FINISHING PIGS FED CORN-, SORGHUM-, WHEAT-, AND WHEAT MIDDS-BASED DIETS

*S. L. Traylor [1], J. D. Hancock, K. C. Behnke [1], R. H. Hines, D. J. Lee, S. L. Johnston, and P. Sorrell*

## Summary

Expander processing of corn-, sorghum-, wheat-, and wheat midds-based diets improved nutrient digestibility in growing pigs and, thus, the apparent digestible energy concentration in the diets. This new feed manufacturing technology was especially beneficial to the feedstuff with the highest fiber content (i.e., wheat midds).

(Key Words: Expander, Corn, Sorghum, Wheat Midds.)

## Introduction

Expander and extrusion processing have similar processing principles; however, expanders have been designed for increased throughput, decreased energy consumption, and lower installation costs compared to extrusion processing. Because expander technology is relatively new to the US feed industry, few data are available that illustrate the effects of expander processing on growth performance and nutrient digestibility in pigs. Thus, we designed a series of experiments to determine the effects of expander processing conditions on nutrient digestibility with several cereal grains commonly used in diets for finishing pigs.

## Procedures

Corn was hammermilled through a 1/8 in. screen and blended into diets. The diets were corn-soybean meal-based with .85% lysine, .65% Ca, .55% P, and 1.57 Mcal of DE/lb (Table 1.). They were steam conditioned to 160°F; processed through a 100 horsepower expander (Amandus-Kahl, Model OE15.2); and pelleted with a 30 horsepower California Pellet Mill. The pellet mill had a 1.5in.-thick die with 3/16 in.-diameter holes. The diets were processed with no pressure and 166, 333, and 500 psi cone pressure before pelleting. Production rate was held constant at .9 tons/h. The pellet mill and expander motors were equipped with a recording volt-amp meter to allow calculation of electrical energy consumption. Specific energy consumption was calculated as the difference between total energy during processing and idle energy consumption.

Pellet samples were collected immediately after exiting the pellet die and cooled with ambient air. The cooled pellets were analyzed for pellet durability index (PDI) using the standard procedures and also using the standard procedures with five ½ in. hexagonal nuts added to the pellets before tumbling. Processing treatments were replicated three times for each experiment to allow statistical analyses.

A total of 32 pigs (average initial BW of 158 lb) was used in the digestibility assay. The pigs were blocked by weight and sorted by sex and ancestry into pens (6 ft × 16 ft) in a modified open-front finishing facility. There were eight pigs per pen and four pens per treatment. Feed and water were consumed on an ad libitum basis. The pigs were fed diets with .20% chromic oxide for 4 d, and grab samples of feces were collected at 6:00 p.m. on d 4 and 6:00 a.m. on d 5. The fecal samples were dried; pooled within pen; and

[1]Department of Grain Science and Industry.

analyzed for DM, N, GE, and Cr to allow calculation of apparent nutrient digestibility using the indirect ratio method.

In the second experiment, 136 pigs (average initial BW of 92 lb) were used. There were 17 pigs per pen and four pens per treatment. A sorghum-soybean meal-based diet was formulated to 1.1% lysine, .65% Ca, .55% P, and 1.53 Mcal of DE/lb. In the third experiment, 136 pigs (average initial BW of 91 lb) were used. There were 17 pigs per pen and four pens per treatment. The wheat-soybean meal-based diet was formulated to 1.1% lysine, .65% Ca, .55% P, and 1.53 Mcal of DE/lb. In the fourth experiment, 32 pigs (average initial BW of 159 lb) were used. There were eight pigs per pen and four pens per treatment. The diet had 50% wheat midds and was formulated to .85% lysine, .65% Ca, .55% P, and 1.47 Mcal of DE/lb. For Exps. 2, 3, and 4, feed manufacturing processes, pig management, and sample collection and analyses were the same as in Exp 1.

All data were analyzed as a randomized complete block design with pen as the experimental unit. Polynomial regression was used to characterize the shape of the response curve as cone pressure was increased.

## Results and Discussion

For the corn-based diet (Table 2), total and specific energies for expanding increased as cone pressure were increased (linear and quadratic effects, P<.002). Pellet durability index was increased from 68.5% with no cone pressure (i.e., standard steam conditioning at atmospheric pressure) to 95.5% at 500 psi of cone pressure (P<.001). Starch damage (i.e., gelatinization and shear) increased with increased cone pressure and seemed to plateau at 333 psi.

Maximum digestibilities of DM (P<.07), N (P<.003), and GE (P<.10) were achieved at 333 psi. This cone pressure (31.6 kWh/ton of specific energy into the feed) yielded a diet with 1.54 kcal/lb of DE.

For the sorghum-based diet (Table 3), total and specific energies for expanding increased as cone pressure was increased (linear and quadratic effects, P<.001). Pellet durability index was increased from 77.2% with no cone pressure to 92.8% with 333 psi cone pressure (quadratic effect, P<.06). Starch damage was increased from 26 % with no cone pressure to 62% at 500 psi. Maximum nutrient digestibility was achieved at 166 psi (9.1 kWh/ton of specific energy into the feed), yielding a diet with 1,618 kcal/lb of DE (quadratic effect, P<.001).

For the wheat-based diet (Table 4), total and specific energy usages responded as they did for corn and sorghum-based diets. However, with no cone pressure, the PDI of wheat-based diets was 92.6% (compared to 68.5% and 77.2% for the corn- and sorghum-based diets). Wheat is known for its contribution toward pellet durability, and 5 to 10% wheat sometimes is added to a problematic formulation to bolster pellet quality.

Another difference between this wheat-based diet and the corn- and sorghum-based diets was the general lack of response (P>.15) in digestibilities of DM, N, and GE with increased cone pressure. Nonetheless, a linear increase (P<.006) in DE of the wheat-based diet occurred as cone pressure was increased, with 1,549 kcal/lb of DE at 500 psi (32.1 kWh/ton of specific energy into the feed).

For the wheat midds-based diet (Table 5), total and specific energy usages increased with increased cone pressure (linear effect, P<.001). Pellet durability index increased from 84.2% to 89.2% as cone pressure was increased but seemed to plateau at 166 psi. Digestibilities of DM, N, and GE, and the actual DE of the diet all increased with increasing cone pressure (linear effects, P<.02). Indeed, increasing cone pressure from none to 500 psi (i.e., up to 34 kWh/ton of specific energy into the feed) increased the DE content of the diet by nearly 200 kcal/lb (i.e., from 1,233 to 1,417). This response suggests that fibrous feedstuffs (e.g., wheat midds) may have more to gain from expander

processing than low-fiber cereal grains (e.g., corn and wheat).

In conclusion, expander processing tended to increase nutrient digestibility and, therefore, the energy value of all diets we tested. The DEs of corn-, sorghum-, wheat-, and wheat midds-based diets were increased by 70, 100, 50, and 200 kcal/lb, respectively.

**Table 1. Diet Compositions for Exp. 1, 2, 3, and 4[a]**

| Ingredient, % | Exp. 1[a] | Exp. 2[b] | Exp. 3[b] | Exp. 4[c] |
|---|---|---|---|---|
| Corn | 80.28 | -- | -- | 41.35 |
| Grain sorghum | -- | 70.14 | -- | -- |
| Hard red winter wheat | -- | -- | 78.10 | -- |
| Wheat middlings | -- | -- | -- | 50.00 |
| Soybean meal (46.5% CP) | 15.43 | 25.48 | 17.49 | 4.81 |
| Soybean oil | 1.00 | 1.00 | 1.00 | 1.00 |
| Monocalcium phosphate | 1.07 | .89 | .70 | -- |
| Limestone | 1.03 | 1.04 | 1.17 | 1.47 |
| Salt | .30 | .30 | .30 | .30 |
| Vit/Min/AA/Ab[d] | .69 | .95 | 1.04 | .87 |
| Chromic oxide[e] | .20 | .20 | .20 | .20 |

[a]Formulated to .85% lysine, .65% Ca, .55% P, and 1.57 Mcal of DE/kg.
[b]Formulated to 1.1% lysine, .65% Ca, .55% P, and 1.53 Mcal of DE/kg.
[c]Formulated to .85% lysine, .65% Ca, .55% P, and 1.47 Mcal of DE/kg.
[d]Provided 100 g/ton tylosin.
[e]Used as an indigestible marker.

**Table 2. Effects of Cone Pressure on Diet Characteristics and Nutrient Digestibility of Corn-Based Diets in Finishing Pigs**

| | Cone Pressure, psi | | | | | Probability, P < | | |
|---|---|---|---|---|---|---|---|---|
| Item | 0 | 166 | 333 | 500 | SE | Linear | Quadratic | Cubic |
| Electrical energy consumption, kWh/t | | | | | | | | |
| Expander | | | | | | | | |
| Total | 24.7 | 34.0 | 57.4 | 82.4 | 1.5 | .001 | .002 | .12 |
| Specific[a] | .4 | 9.4 | 31.6 | 57.0 | 1.2 | .001 | .001 | .11 |
| Pellet mill | 13.9 | 11.0 | 10.6 | 11.3 | .2 | .001 | .001 | .09 |
| Overall | 38.6 | 45.0 | 68.0 | 93.7 | 1.5 | .001 | .001 | .09 |
| Pellet durability index, %[b] | | | | | | | | |
| Standard[c] | 68.5 | 90.7 | 93.3 | 95.5 | .3 | .001 | .001 | .001 |
| Modified[d] | 44.7 | 85.2 | 92.0 | 94.7 | .3 | .001 | .001 | .001 |
| Starch damage, % | 32.0 | 44.3 | 48.9 | 49.9 | - | - | - | -[g] |
| Apparent nutrient digestibility, %[e] | | | | | | | | |
| DM | 81.4 | 84.3 | 86.5 | 85.9 | .8 | .005 | .07 | - |
| N | 77.5 | 81.1 | 83.8 | 82.8 | .5 | .001 | .003 | - |
| GE | 82.5 | 85.3 | 87.2 | 86.5 | .9 | .02 | .10 | - |
| DE of diet, k/cal/lb[f] | 1,469 | 1,483 | 1,540 | 1,510 | 15 | .04 | - | .11 |

[a]Difference between total and idle energy consumption
[b]Three replicates/treatment.
[c]Am. Soc. Agric. Engin. method.
[d]Am. Soc. Agric. Engin. method with the addition of five 1/2 in. hexagonal nuts prior to tumbling.
[e]A total of 36 pigs (eight pigs/pen with an average initial BW of 158 lb) with three pens/-treatment.
[f]Calculated as apparent GE digestibility (%) × GE of the diet (Mcal/kg).
[g]Dashes indicate P>.15

**Table 3. Effects of Cone Pressure on Diet Characteristics and Nutrient Digestibility of Sorghum-Based Diets in Finishing Pigs**

| | Cone Pressure, psi | | | | | Probability, P < | | |
|---|---|---|---|---|---|---|---|---|
| Item | 0 | 166 | 333 | 500 | SE | Linear | Quadratic | Cubic |
| Electrical energy consumption, kWh/t | | | | | | | | |
| Expander | | | | | | | | |
| Total | 23.2 | 31.9 | 38.1 | 55.8 | .5 | .001 | .001 | .001 |
| Specific[a] | .2 | 9.1 | 15.6 | 33.1 | .6 | .001 | .001 | .003 |
| Pellet mill | 12.8 | 10.8 | 10.0 | 11.1 | .3 | .006 | .002 | - |
| Overall | 36.0 | 42.7 | 48.1 | 66.9 | .5 | .001 | .001 | .001 |
| Pellet durability index, %[b] | | | | | | | | |
| Standard[c] | 77.2 | 90.6 | 92.8 | 90.8 | 3.2 | .04 | .06 | -[g] |
| Modified[d] | 60.6 | 84.5 | 90.2 | 87.6 | 6.0 | .03 | .07 | - |
| Starch damage, % | | | 41.9 | | NA | NA | NA | NA |
| | 26.0 | 37.3 | | 61.7 | | | | |
| Apparent nutrient digestibility, %[e] | | | | | | | | |
| DM | 85.5 | 87.1 | 86.2 | 86.2 | .3 | - | .006 | .006 |
| N | 78.3 | 80.3 | 81.0 | 80.3 | .6 | .01 | .02 | - |
| GE | 85.5 | 87.8 | 86.5 | 86.6 | .3 | .09 | .001 | .001 |
| DE of diet, | | | | | | | | |
| kcal/lb[f] | 1,516 | 1,618 | 1,555 | 1,572 | 4 | .001 | .001 | .001 |

[a]Difference between total and idle energy consumption. [b]Three replicates/treatment. [c]Am. Soc. Agric. Engin. method. [d]Am. Soc. Agric. Engin. method with the addition of five 1/2 in. hexagonal nuts prior to tumbling. [e]A total of 136 pigs (17 pigs/pen with an average initial BW of 92 lb) and four replicates/treatment. [f]Calculated as apparent GE digestibility (%) × GE of the diet (Mcal/kg). [g]Dashes indicate P>.15.

**Table 4. Effects of Cone Pressure on Diet Characteristics and Nutrient Digestibility of Wheat-Based Diets in Finishing Pigs**

| | Cone Pressure, psi | | | | | Probability, P < | | |
|---|---|---|---|---|---|---|---|---|
| Item | 0 | 166 | 333 | 500 | SE | Linear | Quadratic | Cubic |
| Electrical energy consumption, kWh/t | | | | | | | | |
| Expander | | | | | | | | |
| Total | 22.9 | 31.7 | 37.4 | 54.5 | .7 | .001 | .001 | .005 |
| Specific[a] | .2 | 8.7 | 14.8 | 32.1 | .5 | .001 | .001 | .002 |
| Pellet mill | 14.8 | 10.6 | 10.2 | 11.0 | .2 | .001 | .001 | .05 |
| Overall | 37.7 | 42.3 | 47.6 | 65.5 | .8 | .001 | .001 | .02 |
| Pellet durability index, %[b] | | | | | | | | |
| Standard[c] | 92.6 | 95.3 | 95.5 | 94.5 | .3 | .004 | .001 | -[g] |
| Modified[d] | 88.5 | 91.9 | 93.3 | 92.5 | .2 | .001 | .001 | - |
| Starch damage, % | 16.8 | 28.7 | 31.5 | 49.1 | - | - | - | - |
| Apparent nutrient digestibility %[e] | | | | | | | | |
| DM | 85.7 | 84.5 | 85.1 | 85.2 | .6 | - | - | - |
| N | 83.7 | 83.2 | 83.5 | 83.8 | .7 | - | - | - |
| GE | 85.8 | 84.6 | 85.1 | 85.6 | .7 | - | - | - |
| DE of diet, | | | | | | | | |
| kcal/lb[f] | 1,499 | 1,517 | 1,529 | 1,549 | 11 | .006 | - | - |

[a]Difference between total and idle energy consumption. [b]Three replicates/treatment. [c]Am. Soc. Agric. Engin. method. [d]Am. Soc. Agric. Engin. method with the addition of five 1/2" hexagonal nuts prior to tumbling. [e]A total of 136 pigs (17 pigs/pen with an average initial BW of 91 lb) with four pens/treatment. [f]Calculated as apparent GE digestibility (%) × GE of the diet (Mcal/kg). [g]Dashes indicate P>.15.

**Table 5. Effects of Cone Pressure on Diet Characteristics and Nutrient Digestibility of Wheat Midds-Based Diets in Finishing Pigs**

| | Cone Pressure, psi | | | | | Probability, P < | | |
|---|---|---|---|---|---|---|---|---|
| Item | 0 | 166 | 333 | 500 | SE | Linear | Quadratic | Cubic |
| Electrical energy consumption, kWh/t | | | | | | | | |
| Expander | | | | | | | | |
| Total | 25.5 | 33.8 | 43.6 | 60.0 | 2.2 | .001 | .12 | -[g] |
| Specific[a] | .3 | 8.5 | 18.3 | 34.0 | 2.2 | .001 | .14 | - |
| Pellet mill | 12.6 | 10.4 | 9.9 | 10.0 | .2 | .001 | .001 | - |
| Overall | 38.1 | 44.2 | 53.5 | 70.0 | 2.2 | .001 | .06 | - |
| Pellet durability index, %[b] | | | | | | | | |
| Standard[c] | 84.2 | 89.1 | 87.0 | 89.2 | 1.1 | .05 | - | .09 |
| Modified[d] | 73.0 | 83.9 | 76.7 | 87.6 | 4.6 | .13 | - | .13 |
| Starch damage, % | 33.8 | 51.7 | 51.9 | 69.9 | - | - | - | - |
| Apparent nutrient digestibility, %[e] | | | | | | | | |
| DM | 70.0 | 72.6 | 72.4 | 75.6 | 1.2 | .02 | - | - |
| N | 69.2 | 74.5 | 77.1 | 78.3 | 1.2 | .001 | - | - |
| GE | 69.8 | 73.8 | 74.5 | 77.0 | .9 | .002 | - | - |
| DE of diet, kcal/lb[f] | 1,233 | 1,347 | 1,357 | 1,417 | 17 | .001 | - | - |

[a]Difference between total and idle energy consumption.
[b]Three replicates/treatment.
[c]Am. Soc. Agric. Engin. method.
[d]Am. Soc. Agric. Engin. method with the addition of five 1/2" hexagonal nuts prior to tumbling.
[e]A total of 36 pigs (eight pigs/pen with an average initial BW of 159 lb) with three pens/treatment.
[f]Calculated as apparent GE digestibility (%) × GE of the diet (Mcal/kg).
[g]Dashes indicate P>.15.

**Eldo Heller, Breeding Barn Manager.**

# EXPANDER PROCESSING AND ENZYMES FOR A WHEAT-BASED DIET FOR FINISHING PIGS [1]

***J. S. Park, J. D. Hancock, R. H. Hines, K. C. Behnke [2], G. A. Kennedy [3], J. D. DeRouchey, D. J. Lee, C. A. Maloney, and H. Cao***

## Summary

Overall ADG and ADFI were not affected, but feed efficiency was improved with pelleting and further improvements resulted from expander processing. In a second experiment, enzyme supplementation to mash, but not pelleted, diets improved feed efficiency. Indeed, F/G for pigs fed mash with enzyme was similar to that for pigs fed pelleted diets.

(Key Words: Expander, Wheat, Enzyme, Finishing Pigs.)

## Introduction

Recent experiments demonstrated enhanced nutrient utilization and improved growth performance when barley-based diets supplemented with β-glucanase were fed to poultry. Furthermore, phytase and β-glucanase have been used in swine diets to improve digestibilities of phosphorus and complex carbohydartes. In a previous Swine Day Report, we demonstrated that wheat has a feeding value approximately 92% that of corn. Thus, a means of improving nutrient utilization from wheat would be of great benefit. The objective of the experiments reported herein was to determine the effects of pelleting and expanding a wheat-based diet and of wheat-specific enzymes on growth performance and nutrient digestibility.

## Procedures

In Exp. 1, 60 crossbred gilts (PIC line 326 sires × C22 dams; average initial BW of 109 lb) were used in a 70-d growth assay. The pigs were blocked by weight and allotted to treatments based on ancestry. There were two pigs per pen (5-ft × 5-ft with slatted concrete floors) and 10 pens/treatment in an environmentally controlled building. Each pen had a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. Treatments were: 1) mash; 2) standard pellet; and 3) expanded pellet. The diets (Table 1) were formulated to .9% lysine for Phase 1 (d 0 to 33) and .7% lysine for Phase 2 (d 33 to 70).

At approximately midexperiment (d 33), chromic oxide (.25%) was added to the diets as an indigestible marker. After a 4-d adjustment period, fecal samples were collected from two pigs per pen, pooled within pen, and frozen. Later, the feces were oven-dried at 122°F for 72 h and ground. Feed and feces were analyzed for concentrations of DM, N, and Cr to allow calculation of apparent digestibilities of DM and N.

The pigs were slaughtered when those in the heaviest pen in a weight block reached an average BW of 250 lb. Dressing percentage (hot carcass weight/final live weight × 100) and last rib backfat thickness (measured on the midline of the split carcass) for each pig were adjusted (using regression analysis) to the average final BW before being pooled within pen. Also, fat-free lean index for each

[1] Appreciation is expressed to Dr. Craig Wyatt of FinnFeed International for suggesting and funding for this project.

[2]Department of Grain Science and Industry.

[3]Department of Diagnostic Medicine/Pathobiology.

pen was calculated using the equation proposed by the National Pork Producers Council (1994). Response criteria were ADG, ADFI, F/G, apparent digestibilities of DM and N, dressing percentage, backfat thickness, fat-free lean index, and scores for stomach keratosis and ulceration.

**Table 1. Basal Diets**

| Ingredient, % | Period 1[a] | Period 2[b] |
|---|---|---|
| Wheat (hard red winter) | 85.96 | 90.95 |
| Soybean meal (46.5% CP) | 9.51 | 4.72 |
| Soybean oil | 1.00 | 1.00 |
| Lysine-HCL | .38 | .41 |
| DL-methionine | .03 | .02 |
| Monocalcium phosphate | 1.55 | 1.20 |
| Limestone | .66 | .60 |
| Salt | .30 | .30 |
| Enzyme[c] | - | - |
| Vitamins, trace minerals, and antibiotic[d] | .61 | .80 |
| Total | 100.00 | 100.00 |

[a]Formulated to .90% lysine, .65% Ca, and .55% P and fed from d 0 to 33 and d 0 to 34 in Exps. 1 and 2, respectively.
[b]Formulated to .70% lysine, .55% Ca, and .45% P and fed from d 33 to 55 and d 34 to 70 in Exps. 1 and 2, respectively.
[c]Porzyme™ 9300 (Finnfeed Interational, Schaumburg, IL) powder was added as .1% of the finished diets and Porzyme™ 9310 liquid was sprayed on as .05% of finished diets after pelleting.
[d]Supplied 100g/ton tylosin.

In Exp. 2, 80 crossbred gilts (PIC line326 sires × C-22 dams; average initial BW of 123 lb) were used in a 55-d growth assay. The pigs were blocked by weight and allotted to treatments based on ancestry. There were two pigs per pen (5-ft by 5-ft with slatted concrete floors) and five pens/treatment. Pig and feeder managements were the same as in Exp. 1. Treatments were : 1) mash; 2) mash with xylanase (from *Trichoderma longibrachiatium)* with 4,000 xylanase units/g of product; 3) pellets; 4) pellets with xylanase added at the mixer; 5) pellets with xylanase sprayed on after pelleting; 6) expanded pellets; 7) expanded pellets with xylanase added at the mixer; and 8) expanded pellet with xylanase sprayed on after pelleting. The diets (Table 1) were formulated to .9% lysine for Phase 1 (d 0 to 34) and .7% lysine for Phase 2 (d 34 to 55).

At approximately midexperiment (d 34), chromic oxide (.25%) was added to the diets as an indigestible marker. After a 4-d adjustment period, fecal samples were collected from two pigs per pen, pooled within pen, and frozen. Later, the feces were oven-dried at 122°F for 72 h and ground. Slaughter procedure and collecting of carcass data were the same as in Exp. 1.

All data were analyzed as a randomized complete block design (with BW as the blocking criterion) using the GLM procedure of SAS. Orthogonal contrasts were used to separate treatment means with pen as the experimental unit.

## Results and Discussion

For Exp. 1, overall F/G ($P<.02$) and digestibility of DM ($P<.01$) and N ($P<.02$) were improved by pelleting the diet. Also, for overall period, expander processing improved F/G ($P<.02$) and digestibility of DM ($P<.04$) compared to standard steam conditioning. These results are similar to previous reports from our laboratory, in which pelleting of cereal-based diets increased nutritional value. However, studies with poultry indicate that expander processing of wheat-based diets causes increased viscosity of digesta that reduces nutrient utilization. Our data do not suggest similar effects (i.e., reduced nutritional value) when wheat-based diets are expanded and fed to pigs.

Dressing percentage was not affected by treatments ($P>.3$), but fat-free lean index was lower for pigs fed pelleted diets ($P<.03$). This likely was caused by the greater energy value (e.g., greater digestibility of DM) when the diet was pelletized. Stomach ulceration ($P<.003$) and keratinization ($P<.002$) were increased by pelleting. However, the mean score for the various treatments ranged from .05 to 1.08 (i.e., from essentially low to mild

keratosis and ulceration), suggesting that no treatment caused severe stomach lesions.

For Exp. 2, pelleting decreased F/G from d 0 to 36 (P<.02) and overall (P<.05) and tended (P<.11) to increase digestibility of DM. However, expander processing did not improve F/G or digestibility of nutrients compared to standard steam conditioning (P>.27). Adding the xylanase enzyme to the mash diet improved overall efficiency of growth (P<.01) and digestibility of DM (P<.05). However, the effects of pelleting and enzyme supplementation were not additive (e.g., neither blending the powdered enzyme supplement into the diet before pelleting nor spraying the liquid enzyme on the pellets at the cooler was beneficial).

Pelleting trended to increase scores for ulceration (P<.06), but as in Exp. 1, the means for all treatments were low (ranging from normal to mild). Enzyme supplementation decreased keratinization scores for pigs fed the standard pellets (P< .01) but increased scores for pigs fed expanded pellets (standard vs expander pellets × enzyme addition interaction, P<.01). Scores for ulceration were not affected by enzyme supplementation.

In conclusion, our results demonstrated that pelleting improved feed efficiency and nutrient digestibility. In addition, expander processing resulted in further improvements in F/G. Also, enzyme supplementation to a wheat-based, mash diet improved feed efficiency and nutrient digestibility to a level approaching that with the pelletized diet. However, enzyme addition did not further improve the nutritional value of pelletized, wheat-based diets for finishing pigs.

**Table 2. Growth Performance of Finishing Pigs (Exp. 1)[a]**

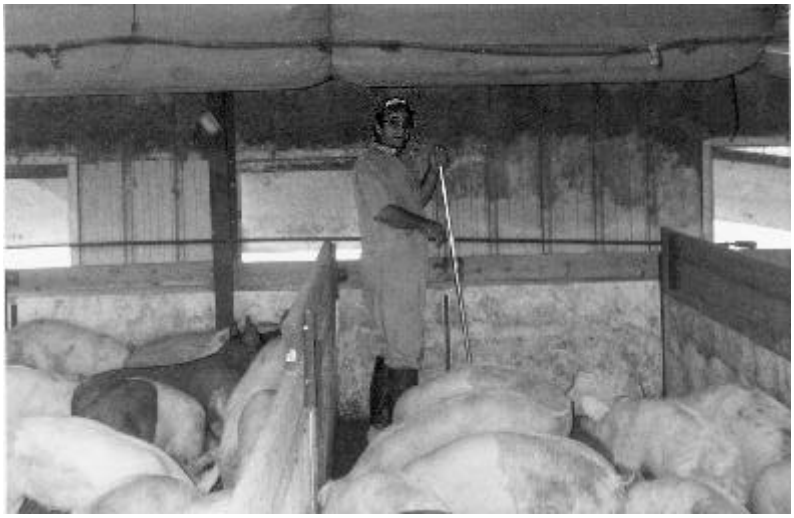
| | Treatments | | | | Contrast | |
|---|---|---|---|---|---|---|
| Item | Mash | Standard pellet | Expanded pellet | SE | 1 | 2 |
| Day 0 to 33 | | | | | | |
| ADG, lb | 1.83 | 1.89 | 1.88 | .08 | - | - |
| ADFI, lb | 4.86 | 4.83 | 4.68 | .19 | - | - |
| F/G | 2.63 | 2.57 | 2.50 | .09 | - | - |
| Day 33 to 70 | | | | | | |
| ADG, lb | 2.01 | 2.02 | 2.17 | .19 | - | - |
| ADFI, lb | 5.96 | 5.92 | 5.97 | .20 | - | - |
| F/G | 2.98 | 2.95 | 2.76 | .12 | - | .06 |
| Overall | | | | | | |
| ADG, lb | 1.93 | 1.95 | 2.03 | .07 | - | - |
| ADFI, lb | 5.45 | 5.41 | 5.36 | .16 | - | - |
| F/G | 2.83 | 2.77 | 2.64 | .66 | .02 | .03 |
| Digestibility (d 37), % | | | | | | |
| DM | 85.4 | 86.9 | 87.6 | .4 | .01 | .04 |
| N | 80.0 | 82.2 | 82.9 | 1.6 | .02 | - |
| Carcass measurements [c] | | | | | | |
| DP, % | 74.9 | 74.9 | 74.9 | .5 | - | - |
| BF, in | .96 | 1.02 | 1.04 | .04 | .04 | - |
| FFLI, % | 46.3 | 45.4 | 45.4 | .5 | .03 | - |

[a]A total of 60 finishing pigs was fed from an average initial BW of 109 lb to an average final BW of 246 lb.
[b]Contrasts were: 1) mash vs pellets and 2) standard pellet vs expanded pellets.
[c]DP = dressing percentage, BF = tenth rib backfat thickness, and FFLI = fat-free lean index (NPPC, 1994).
[d]Dash indicates P>.15.

Table 3 Stomach Morphology of Finishing Pigs (Exp. 1)

| | Treatments | | | | Contrast | |
|---|---|---|---|---|---|---|
| Item | Mash | Standard pellet | Expanded pellet | SE | 1 | 2 |
| Keratinization[c] | | | | | | |
| Total observations | 20 | 20 | 17 | | | |
| Normal | 13 | 2 | 3 | | | |
| Mild | 6 | 13 | 11 | | | |
| Moderate | 1 | 4 | 3 | | | |
| Severe | 0 | 1 | 0 | | | |
| Mean score[d] | .22 | 1.08 | .73 | .38 | .002 | .09 |
| Ulceration[e] | | | | | | |
| Total observations | 20 | 20 | 20 | | | |
| Normal | 19 | 11 | 10 | | | |
| Mild | 1 | 5 | 4 | | | |
| Moderate | 0 | 1 | 1 | | | |
| Severe | 0 | 3 | 5 | | | |
| Mean score[f] | .05 | .70 | 1.00 | .54 | .003 | .32 |

[a]A total of 60 finishing pigs was fed from an average initial BW of 109 lb to an average final BW of 246 lb.
[b]Contrasts were: 1) mash vs pellets; and 2) standard pellets vs expanded pellets.
[c]Scoring system was: 0 = normal; 1 = mild kerosis; 2 = moderate kerosis; and 3 = severe kerosis.
[d]Cochran-Mantel-Haenszel statistic, row mean scores differ test was P<.001.
[e]Scoring system was: 0 = normal; 1 = mild ulceration ; 2 = moderate ulceration; and 3 = severe ulceration.
[f]Cochran-Mantel-Haenszel statistic, row mean scores differ test was P<.01.



**Lyle Figge, Finishing Barn Manager.**

**Table 4. Growth Performance of Finishing Pigs (Exp. 2)[a]**

| | Mash | | Standard Pellet | | | Expanded Pellet | | | | Contrasts[c] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | None | Mixer[b] | None | Mixer[b] | Pellets | None | Mixer[b] | Pellets | SE | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Day 0 to 36 | | | | | | | | | | | | | | | | |
| ADG, lb | 2.39 | 2.33 | 2.35 | 2.31 | 2.32 | 2.25 | 2.40 | 2.21 | .06 | -[e] | - | - | - | - | - | - |
| ADFI, lb | 6.04 | 5.91 | 5.53 | 5.57 | 5.46 | 5.54 | 5.53 | 5.30 | .21 | - | - | - | .12 | - | - | - |
| F/G | 2.53 | 2.54 | 2.35 | 2.41 | 2.35 | 2.47 | 2.31 | 2.40 | .01 | .02 | - | - | - | - | - | - |
| Day 36 to 71 | | | | | | | | | | | | | | | | |
| ADG, lb | 2.34 | 2.58 | 2.67 | 2.31 | 2.33 | 2.66 | 2.52 | 2.53 | .09 | - | - | - | - | - | - | - |
| ADFI, lb | 6.63 | 6.37 | 6.98 | 6.55 | 6.98 | 7.00 | 6.99 | 6.90 | .21 | .09 | - | - | - | - | - | - |
| F/G | 2.84 | 2.55 | 2.62 | 2.84 | 2.99 | 2.62 | 2.77 | 2.72 | .02 | - | .11 | - | .07 | - | - | - |
| Overall | | | | | | | | | | | | | | | | |
| ADG, lb | 2.37 | 2.42 | 2.47 | 2.32 | 2.33 | 2.41 | 2.44 | 2.33 | .05 | - | - | - | .12 | - | - | - |
| ADFI, lb | 6.48 | 6.09 | 6.08 | 5.95 | 6.04 | 6.09 | 6.08 | 5.92 | .17 | - | - | - | - | - | - | - |
| F/G | 2.74 | 2.52 | 2.46 | 2.57 | 2.59 | 2.53 | 2.49 | 2.53 | .01 | .05 | .01 | - | - | - | - | - |
| Digestibility (d 39), % | | | | | | | | | | | | | | | | |
| DM | 85.5 | 86.8 | 86.7 | 86.7 | 86.7 | 87.4 | 85.9 | 87.0 | 1.2 | .11 | .05 | - | - | - | - | - |
| N | 86.1 | 87.5 | 85.8 | 86.8 | 87.0 | 86.8 | 85.6 | 86.6 | 2.2 | - | - | - | - | - | - | - |
| Carcass measurement [d] | | | | | | | | | | | | | | | | |
| DP, % | 76.8 | 75.9 | 77.2 | 77.1 | 77.1 | 76.9 | 76.7 | 76.0 | 1.7 | - | - | - | - | - | - | - |
| BF, in | 1.13 | 1.16 | 1.14 | 1.05 | 1.06 | 1.12 | 1.15 | 1.12 | .03 | - | - | - | - | - | - | - |
| FFLI, % | 44.4 | 44.3 | 44.7 | 45.5 | 45.6 | 44.7 | 44.5 | 44.7 | 3.0 | - | - | - | - | - | - | - |

[a]A total of 80 finishing pigs was fed from an average initial BW of 119 lb to an average final BW of 255 lb.
[b]'Mixer' means the enzyme was added at the mixer, in powdered form. 'Pellets' means the enzyme was sprayed onto the pellets in liquid form at the cooler.
[c]Contrasts were: 1) mash vs pellets; 2) mash vs mash+xylanase; 3) standard pellets vs expanded pellets; 4) pellets vs pellets + xylanase; 5) standard pellets vs expanded pellets × pellets vs pellets + xylanase; 6) before vs after; and 7) standard pellets vs expanded pellets × before vs after.
[d]DP = dressing percentage, BF = tenth rib backfat thickness, and FFLI = fat-free lean index (NPPC, 1994).
[e]Dash indicates P>.15.

**Table 5. Stomach Morphology of Finishing Pigs (Exp. 2)[a]**

| | Mash | | Standard Pellet | | | Expanded Pellet | | | Contrasts[c] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | None | Mixer[b] | None | Mixer[b] | Pellets | None | Mixer[b] | Pellets | SE | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Keratinization[d] | | | | | | | | | | | | | | | | |
| Total observations | 9 | 9 | 10 | 10 | 9 | 9 | 9 | 10 | | | | | | | | |
| Normal | 7 | 1 | 1 | 1 | 3 | 3 | 1 | 1 | | | | | | | | |
| Mild | 1 | 2 | 1 | 5 | 4 | 5 | 4 | 7 | | | | | | | | |
| Moderate | 1 | 6 | 8 | 3 | 1 | 1 | 4 | 2 | | | | | | | | |
| Severe | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | | | | | | | | |
| Mean score[e] | .94 | 1.44 | 1.55 | 1.10 | .83 | .67 | 1.22 | 1.05 | .26 | -[h] | - | - | - | .01 | - | - |
| Ulceration[f] | | | | | | | | | | | | | | | | |
| Total observations | 9 | 9 | 10 | 10 | 9 | 9 | 9 | 10 | | | | | | | | |
| Normal | 8 | 8 | 8 | 7 | 5 | 8 | 6 | 6 | | | | | | | | |
| Mild | 1 | 1 | 0 | 1 | 3 | 1 | 3 | 3 | | | | | | | | |
| Moderate | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | | | | | | | | |
| Severe | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | | | | | | | | |
| Mean score[g] | .05 | .05 | .45 | .55 | .61 | .05 | .33 | .5 | .25 | .06 | - | - | - | - | - | - |

[a]A total of 80 finishing pigs was fed from an average initial BW of 119 lb to an average final BW of 255 lb.
[b]'Mixer' means the enzyme was added at the mixer, in powdered form. 'Pellets' means the enzyme was sprayed onto the pellets in liquid form at the cooler.
[c]Contrasts were: 1) mash vs pellets; 2) mash vs mash+xylanas; 3) standard pellets vs expanded pellets; 4) pellets vs pellets + xylanase; 5) standard pellets vs expanded pellets × pellets vs pellets + xylanase; 6) before pelleting vs after pelleting; and 7) standard pellets vs expanded pellets × before pelleting vs after pelleting.
[d]Scoring system was: 0 = normal; 1 = mild kerosis; 2 = moderate kerosis; 3 = severe kerosis.
[e]Cochran-Mantel-Haenszel statistic, row mean scores differ test was P>.21.
[f]Scoring system was: 0 = normal; 1 = mild ulceration; 2 = moderate ulceration; 3 = severe ulceration.
[g]Cochran-Mantel-Haenszel statistic, row mean scores differ test was P>.39.
[h]Dash indicates P>.15.

# EFFECTS OF ENZYME SUPPLEMENTATION AND PARTICLE SIZE OF WHEAT-BASED DIETS ON NURSERY AND FINISHING PIGS [1]

*I. Mavromichalis, J. D. Hancock, G. A. Kennedy [2], R. H. Hines, J. M. DeRouchey, B. W. Senne, and S. P. Sorrell*

## Summary

In nursery pigs, enzyme supplementation generally had no effect on ADG or F/G, but a trend occurred for greater digestibility of DM in pigs fed enzymes. However, one notable interaction occurred. Enzyme supplementation gave improved F/G at the coarser (1,300 mm) particle size but not at the finer (600 or 400 mm) particle sizes. In finishing pigs, trends for better F/G and digestibilities of DM and N with enzyme supplementation occurred in one experiment (1,300 vs 600 mm) but not in the other experiment (600 vs 400). Thus, the effects of enzyme supplementation were neither large nor consistent, but wheat particle sizes of 600 and 400 mm supported the best growth performances in nursery and finishing pigs, respectively.

(Key Words: Nursery Pigs, Finishing Pigs, Wheat, Enzymes, Particle Size.)

## Introduction

Considerable attention has been given to evaluation of enzyme systems for use in diets for nonruminants. Early experiments demonstrated enhanced nutrient utilization and improved growth performance when barley-based diets were supplemented with b-glucanase and fed to poultry. Recently, phytase and b-glucanase have been used successfully in swine diets to enhance digestibility of phytin phosphorus and to reduce concentration of b-glucans.

In previous Swine Day Reports, we reported that wheat has a feeding value approximately 92% that of corn. One explanation for the lower feeding value may be the presence of pentosans, the nonstarch polysaccharide fraction. During digestion, pentosans increase the viscosity of the gastrointestinal fluid, so the flow of digesta is reduced, nutrients become inaccessible to intestinal secretions, and digestion is impaired. Reduction of the pentosan concentration via exogenous enzyme supplementation could result in better growth performance.

Thus, the objective of the experiments reported herein was to determine the effects of enzyme supplementation and particle size reduction in wheat-based diets on growth performance and nutrient digestibility in nursery and finishing pigs.

## Procedures

In our first experiement, diets formulated with hard red winter wheat were fed without or with a wheat-specific enzyme product (Porzyme™ 9300; Finnfeeds International, Schaumburg, IL). The enzyme product was derived from *Trichoderma longibrachiatium* fermentation 'reesi' bacteria (xylanase activity of at least 4,000 units per gram of product) and was added at .1% of the finished diet. The wheat was ground coarsely (geometric mean particle size ($d_{gw}$) of 1,300 mm) in a two pair-high roller mill and ground to intermediate ($d_{gw}$ of 600 microns) and fine ($d_{gw}$ of 400 mm) particle sizes in a hammer-

[1]Appreciation is extended to Craig Wyatt and Finfeeds International for funding this project.

[2]Department of Diagnostic Medicine and Pathobiology.

mill equipped with 1/6 in. and 1/8 in. screens.

A total of 180 (PIC line 326 sires × C15 and C22 dams) nursery pigs with an average initial BW of 12.5 lb was used in a 35-d growth assay. The pigs were grouped by initial BW and assigned to treatments based on sex and ancestry. There were six pigs per pen and five pens per treatment. Treatments were arranged as a 2 × 3 factorial with main effects of enzyme supplementation (none and .1% of the diet) and particle size (1,300, 600, and 400 mm). The diets (Table 1) were formulated to 1.7, 1.5, and 1.3% lysine for d 0 to 7, 7 to 21, and 21 to 35, respectively.

The pigs were housed in an environmentally controlled nursery facility with 100% woven wire flooring. Each pen (4 ft × 5 ft) was equipped with a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. Temperature at animal level was set initially at 90°F and was lowered by 3°F each week. Pigs and feeders were weighed at initiation and the end of each phase to allow calculation of ADG, ADFI, and F/G. On d 6 and 31, fecal samples were collected (four pigs per pen) by rectal massage; pooled within pen; dried; and analyzed for Cr, DM, and N.

The data were analyzed as a randomized complete block design with a 2 × 3 factorial arrangement of treatments using the GLM procedures of SAS. Treatment comparisons were made using polynomials for unequally spaced treatments in the orthogonal contrasts: 1) no enzyme vs enzyme; 2) particle size linear; 3) no enzyme vs enzyme × particle size linear; 4) particle size quadratic; and 5) no enzyme vs enzyme × particle size quadratic. Pen was the experimental unit.

In Exp. 2, a total of 160 (PIC line 326 sire × C15 and C22 dams) finishing pigs, with an average initial BW of 148 lb was used to determine the effects of enzyme supplementation of coarsely (1,300 mm) and intermediately (600 mm) ground wheat-based diets on growth performance, apparent nutrient digestibility, carcass characteristics, viscosity of intestinal digesta, and stomach morphology. The pigs were grouped by initial BW and assigned to treatments based on sex and ancestry. There were 10 pigs per pen and four pens per treatment. Treatments were arranged as a 2 × 2 factorial with main effects of enzyme supplementation (none and .1% of the diet) and particle size of the wheat(1300 mm vs 400 mm). The enzyme used and feed manufacturing processes were the same as those described for Exp. 1. The diets (Table 2) were formulated to .9 and .8% lysine, .6 and .5% Ca, and .5 and .4% P for the first and second phases, respectively. All other nutrient concentration met or exceeded NRC recommendations, and the diets were fed in meal form.

The pigs were housed in a modified open-front finishing facility with 50% solid-concrete and 50% concrete-slat flooring. Each pen (6 ft × 16 ft) was equipped with a two-hole self-feeder and one nipple waterer to allow ad libitum consumption of feed and water. Pigs and feeders were weighed at the initiation, middle, and conclusion of the growth assay to allow calculation of ADG, ADFI, and F/G. On d 23 (approximately midexperiment), fecal samples were collected (six pigs per pen) by rectal massage, pooled within pen, dried, and ground as described for Exp. 1. Concentrations of Cr, DM, and N in the feces and diets were determined.

When pigs in the heaviest pen in a weight block reached an average BW of 250 lb, the entire block was removed from the growth assay. Two blocks reached the end weight on d 51 and two blocks on d 58 of the experiment. The pigs were shipped at 3:00 a.m. to a commercial slaughter facility and killed at 7:00 a.m.. Hot carcass weight was recorded to allow calculation of dressing percentage. Last rib backfat thickness was measured on each half of the split carcass at the midline, and fat-free lean index was calculated using the equations suggested by the NPPC. Digesta samples (five pigs per pen and two pens per treatment) were collected from the terminal ileum and transferred to our laboratory in an ice bath. The samples were centrifuged, and fluid viscosity was measured at room temperature. Additionally, the esophageal region of each stomach was collected

and scored for severity of keratinization and ulceration. The scoring system used for keratinization was 0 = normal, 1 = mild, 2 = moderate, and 3 = severe keratosis, and that for ulcers was 0 = normal, 1 = erosion, 2 = ulcer, and 3 = severe ulcer.

The data were analyzed as a randomized complete block design with a 2 × 2 factorial arrangement of treatments, using the GLM procedures of SAS. Hot carcass weight was used as a covariate for the analyses of backfat thickness, dressing percentage, and fat-free lean index. Treatment comparisons were made using the orthogonal contrasts: 1) no enzyme vs enzyme; 2) 1,300 vs 600 mm; and 3) no enzyme vs enzyme × 1,300 vs 600 mm. Because stomach scores were categorical data, they were tested initially for significant main effects of enzyme supplementation and particle size using the Cohran-Mantel-Haenszel procedure of SAS (i.e., a row mean scores differ test for categorical data), with pen as the experimental unit.

For Exp. 3, a total of 160 (PIC line 326 sire × C15 and C22 dams) finishing pigs, with an average initial BW of 139 lb, was used to determine the effects of enzyme supplementation of intermediately (600 mm) and finely (400 mm) ground wheat-based diets on growth performance, apparent nutrient digestibility, carcass characteristics, viscosity of intestinal digesta, and stomach morphology. The pigs were grouped by initial BW and assigned to treatments based on sex and ancestry. There were 10 pigs per pen and four pens per treatment. Treatments were arranged as a 2 × 2 factorial with main effects of enzyme supplementation (none and .1% of the diet) and particle size of the wheat (600 vs 400 mm). The diets were formulated to the same nutrient concentrations used in Exp. 2 Housing and management of the pigs was the same as in Exp. 2.

Two blocks reached the targeted end weight of 250 lb on d 53 and two blocks on d 61 of the experiment. Slaughter procedures and collection of carcass data, digesta, and stomach tissues were the same as in Exp. 2, with the exception that digesta was collected from five pigs per pen in four pens per treatment. Laboratory analyses and statistical treatment of data were the same as in Exp. 2.

## Results and Discussion

Laboratory analyses (Table 3) indicated that nutrient content was typical (11% moisture and 13.9% CP) for hard red winter wheat. A noteworthy exception was that pentosans were 28.7 g/lb. This value, although not unusual for the hard red wheat grown in Kansas, is quite low compared to some varieties grown elsewhere in the world (e.g., Canada and Europe). Also, mean particle sizes of the ground grain was very close to the targeted particle sizes of 1,300, 600, and 400 mm (Table 4).

For d 0 to 7 of the nursery experiement, a quadratic increase ($P<.04$) in F/G occurred as particle size was reduced, with 600 mm supporting the greatest efficiency of growth (Table 5). Overall (d 0 to 35) , the best ADG (quadratic effect, $P<.01$) and F/G also were achieved at 600 mm. However, the effects of diet particle size and enzyme supplementation were not independent, with decreasing particle size improving overall F/G primarily in the diets without enzyme (enzyme supplementation × particle size quadratic effect, $P<.01$).

For finishing pigs (Exp. 2), ADG was not influenced ($P>.15$) by enzyme supplementation, but a trend ($P<.10$) for improved F/G occurred from 148 to 205 lbs. Also, enzyme supplementation resulted in trends for increased apparent digestibilities of DM ($P<.10$) and N ($P<.07$). Feed/gain was improved by reduced particle size in the 205 to 253 lb phase ($P<.03$), with numerical differences in favor of the smaller particle size overall. Reduced particle size also increased digestibilities of DM ($P<.02$) and N ($P<.04$).

Dressing percentage, last rib backfat thickness, and fat-free lean index were not influenced ($P>.45$) by the dietary treatments. Viscosity of the digesta also was not influenced by the dietary treatments ($P>.42$). This is in agreement with other research reports suggesting that digesta viscosity is not influenced easily in pigs and, therefore,

probably not a factor that routinely affects nutrient digestibility.

Keratinization score was greater (P<.01) in pigs fed the 600 versus 1,300 mm treatments (Table 7). However, stomach ulceration was not affected by reducing particle size to 600 mm (P>.15). These results are in contrast with some reports suggesting that wheat-based diets should be coarsely ground to avoid ulcer development in finishing pigs. Apparently, a combination of stressful factors is needed for pigs to develop stomach ulcers and, thus, blaming increased incidence of stomach lesions on finely ground, wheat-based diets is overly simplistic.

For the final finishing pig experiment (Exp. 3), enzyme supplementation increased ADG (P<.04) in the 198 to 253 lb phase of growth ( Table 8). However, no other enzyme-related effects were observed (P>.11) for growth performance or digestibility of nutrients. Reducing particle size from 600 to 400 mm resulted in better F/G (P<.05) for the 139 to 198 lb and overall (P <.0 4) periods and better apparent digestibilities of DM and N (P<.01).

Carcass characteristics were not affected by enzyme treatment (P>.15); however, a trend (P<.06) occurred for reduced backfat thickness and, consequently, increased fat-free lean index as $_{dgw}$ was reduced from 600 to 400 mm. Digesta viscosity was not influenced (P>.50) by the enzyme or particle size (P>15) treatments.

Stomach morphology was not affected by enzyme supplementation of the diets, but stomach keratinization and ulceration were increased (P<.01) as wheat particle size was reduced from 600 to 400 mm. However, these differences were not associated with negative effects on growth performance. In conclusion, enzyme supplementation had beneficial effects but they were not large or consistent. Our results do not preclude the potential for a larger response to enzyme supplementation in diets based on wheat with greater pentosan content. Also, particle sizes of 400 to 600 mm improved F/G compared to 1,300 mm.

Jarrod Nash, undergrad. & Mark Nelson, Swine Farm Mgr

**Table 1. Compositions of Nursery Diets**

| Item | Phase 1 | Phase 2 | Phase 3 |
|---|---|---|---|
| Ingredients, % | | | |
| Wheat (hard red winter) | 32.89 | 54.30 | 70.46 |
| Soybean meal (46.5% CP) | 16.78 | 26.63 | 22.81 |
| Edible grade whey | 20.00 | 10.00 | - |
| Lactose | 10.00 | - | - |
| Menhaden fish meal | 5.00 | 1.00 | - |
| Spray-dried porcine plasma | 4.00 | - | - |
| Spray-dried wheat gluten | 4.00 | - | - |
| Spray-dried blood meal | 1.00 | 1.00 | - |
| Soybean oil | 2.00 | 2.00 | 1.00 |
| Monocalcium phosphate | 1.29 | 1.90 | 2.19 |
| Limestone | .42 | .71 | .81 |
| Salt | .10 | .20 | .30 |
| Vitamin premix | .25 | .25 | .25 |
| Trace mineral premix | .15 | .15 | .15 |
| Zinc oxide | .39 | .19 | - |
| Cooper sulfate | - | - | .09 |
| Lysine HCl | .30 | .34 | .45 |
| DL-methionine | .18 | .19 | .13 |
| Threonine | .05 | .14 | .16 |
| Enzyme[a] | - | - | - |
| Chromic oxide[b] | .20 | - | .20 |
| Antibiotic[c] | 1.00 | 1.00 | 1.00 |
| | | | |
| Calculated analysis | | | |
| Crude protein (N × 6.25), % | 25.80 | 23.50 | 21.20 |
| Lysine, % | 1.70 | 1.50 | 1.30 |
| Ca, % | .90 | .85 | .80 |
| P, % | .80 | .75 | .70 |
| Metabolizable energy, kcal/lb | 1,485 | 1,462 | 1,438 |

[a]Porzyme™ 9300 (Finnfeeds International) was added as .1% of the diets at the expense of corn.
[b]Used as an indigestible marker.
[c]Provided 75 mg of apramycin (Phases I and II) and 25 mg of carbadox (Phase III) per lb of complete diet.

**Table 2. Compositions of Finishing Diets**

| Item | Phase 1 | Phase 2 |
|---|---|---|
| Ingredient, % | | |
| Wheat (hard red winter) | 85.76 | 90.95 |
| Soybean meal (46.5% CP) | 9.51 | 4.72 |
| Soybean oil | 1.00 | 1.00 |
| Monocalcium phosphate | 1.55 | 1.20 |
| Limestone | .66 | .60 |
| Salt | .30 | .30 |
| Vitamin premix | .20 | .20 |
| Trace mineral premix | .15 | .15 |
| Lysine HCl | .38 | .41 |
| DL-methionine | .03 | .02 |
| Threonine | .13 | .12 |
| Enzyme[a] | - | - |
| Chromic oxide[b] | .20 | .20 |
| Antibiotic[c] | .13 | .13 |
| | | |
| Calculated analysis | | |
| Crude protein (N x 6.25), % | 17.0 | 15.5 |
| Lysine, % | .9 | .8 |
| Ca, % | .6 | .5 |
| P, % | .5 | .4 |
| Metabolizable energy, kcal/lb | 1,463 | 1,466 |

[a]Porzyme™ 9300 (Finnfeeds International) was added as .1% of the diets at the expense of corn.
[b]Used as an indigestible marker.
[c]Provided 45.5 mg of tylosin per lb of complete diet.

**Table 3. Chemical Analyses and Physical Characteristics of Hard Red Winter Wheat**

| Item | Amount |
|---|---|
| Bulk density, lb/bu | 52 |
| Foreign material, % | 2.1 |
| | |
| Dry matter, % | 89 |
| Crude protein (N x 6.25), % | 13.9 |
| Ether extract, % | 1.7 |
| Ash, % | 1.7 |
| Crude fiber, % | 1.4 |
| Nitrogen free extract, % | 70.1 |
| Pentosans, g/lb | 28.7 |
| Gross energy, kcal/lb | 1,876 |
| Amino acids, % | |
| Arginine | .63 |
| Histidine | .30 |
| Isoleucine | .44 |
| Leucine | .89 |
| Lysine | .37 |
| Methionine | .21 |
| Phenylalanine | .60 |
| Threonine | .37 |
| Tryptophan | .19 |
| Valine | .58 |

**Table 4. Characteristics of Ground Wheat[a]**

| | Treatment Particle Size, mm | | | | | | |
|---|---|---|---|---|---|---|---|
| | Exp. 1 | | | Exp. 2 | | Exp. 3 | |
| Item | 1,300 | 600 | 400 | 1,300 | 600 | 600 | 400 |
| Geometric mean particle size, mm | 1,352 | 614 | 390 | 1,288 | 628 | 614 | 406 |
| Standard deviation of particle size | 2.04 | 2.22 | 1.99 | 2.06 | 2.21 | 2.24 | 2.02 |
| Surface area, $cm^2/g$ | 43 | 102 | 148 | 46 | 99 | 103 | 143 |
| Distribution of particles, %[b] | | | | | | | |
| Sieve opening, mm | | | | | | | |
| 4,760 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3,360 | .2 | 0 | 0 | .2 | .1 | .1 | .1 |
| 2,380 | 11.7 | .2 | 0 | 10.4 | .2 | .2 | .3 |
| 1,680 | 38.7 | 4.2 | .2 | 35.5 | 4.3 | 4.7 | .5 |
| 1,191 | 25.2 | 17.8 | .9 | 25.8 | 18.9 | 18.3 | 1.2 |
| 841 | 7.7 | 22.2 | 11.9 | 9.7 | 22.0 | 20.6 | 14.1 |
| 594 | 3.5 | 13.8 | 17.4 | 4.5 | 14.0 | 13.8 | 17.6 |
| 420 | 3.4 | 12.3 | 20.1 | 4.0 | 11.9 | 12.5 | 18.0 |
| 297 | 3.4 | 10.4 | 17.6 | 3.6 | 9.7 | 9.4 | 15.0 |
| 212 | 3.1 | 8.7 | 14.2 | 3.3 | 8.9 | 10.4 | 15.1 |
| 150 | 1.2 | 4.0 | 7.0 | 1.2 | 4.0 | 3.7 | 8.8 |
| 103 | .8 | 2.9 | 5.3 | .7 | 2.6 | 2.8 | 6.1 |
| 74 | .8 | 2.4 | 4.1 | .8 | 2.4 | 2.5 | 2.5 |
| 53 | .2 | .8 | 1.0 | .2 | .8 | .8 | .5 |
| Pan | .1 | .3 | .3 | .1 | .2 | .2 | .2 |

[a]Am. Soc. Agric. Engin. method (1995).

**Table 5. Effects of Enzyme Supplementation and Particle Size of Wheat-Based Diets on Growth Performance and Apparent Nutrient Digestibility in Nursery Pigs (Exp. 1)[a]**

| | No Enzyme | | | Enzyme | | | | Contrasts[b] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | 1,300[c] | 600 | 400 | 1,300 | 600 | 400 | SE | 1 | 2 | 3 | 4 | 5 |
| Growth performance | | | | | | | | | | | | |
| Day 0 to 7 | | | | | | | | | | | | |
| ADG, lb | .45 | .59 | .59 | .62 | .62 | .52 | .05 | -[d] | - | .08 | - | - |
| ADFI, lb | .64 | .65 | .64 | .71 | .70 | .59 | .06 | - | .10 | .12 | - | - |
| F/G | 1.42 | 1.10 | 1.08 | 1.14 | 1.13 | 1.13 | .09 | - | .05 | .10 | .04 | .12 |
| Overall (Day 0 to 35) | | | | | | | | | | | | |
| ADG, lb | .90 | 1.00 | .92 | .95 | 1.03 | .92 | .02 | - | - | .09 | .01 | - |
| ADFI, lb | 1.20 | 1.15 | 1.15 | 1.19 | 1.26 | 1.11 | .03 | - | .01 | - | - | .05 |
| F/G | 1.34 | 1.15 | 1.19 | 1.26 | 1.22 | 1.21 | .06 | - | .01 | .14 | .01 | .01 |
| Apparent digestibility, % | | | | | | | | | | | | |
| Day 6 | | | | | | | | | | | | |
| DM | 81.7 | 83.8 | 84.0 | 86.8 | 85.0 | 84.1 | 1.2 | .08 | - | .14 | - | - |
| N | 78.1 | 79.6 | 79.2 | 83.9 | 81.7 | 77.9 | 1.8 | - | - | .12 | - | - |
| Day 31 | | | | | | | | | | | | |
| DM | 85.9 | 87.2 | 85.8 | 86.1 | 87.8 | 88.4 | .7 | .11 | - | - | .12 | - |
| N | 85.4 | 86.9 | 85.5 | 85.5 | 88.0 | 88.5 | 1.1 | - | - | - | - | - |

[a]A total of 180 pigs (six pigs/pen and five pens/treatment) with an avg initial BW of 12.5 lb and an avg final BW of 46 lb.
[b]Contrasts were: 1) no enzyme vs enzyme; 2) particle size linear; 3) no enzyme vs enzyme × particle size linear; 4) particle size quadratic; and 5) no enzyme vs enzyme × particle size quadratic.
[c]Geometrical mean particle size, μm.
[d]Dashes indicate P>.15.

**Table 6. Effects of Enzyme Supplementation and Particle Size of Wheat-Based Diets on Growth Performance and Apparent Nutrient Digestibility in Finishing Pigs (Exp. 2)[a]**

| | No Enzyme | | Enzyme | | | Contrasts[b] | | |
|---|---|---|---|---|---|---|---|---|
| Item | 1,300[c] | 600 | 1,300 | 600 | SE | 1 | 2 | 3 |
| Growth performance | | | | | | | | |
| 148 to 205 lb | | | | | | | | |
| ADG, lb | 2.08 | 2.00 | 2.10 | 2.01 | .04 | -[f] | .10 | - |
| ADFI, lb | 6.45 | 6.48 | 6.37 | 6.23 | .09 | .10 | - | - |
| F/G | 3.10 | 3.23 | 3.04 | 3.10 | .01 | .10 | - | - |
| 205 to 253 lb | | | | | | | | |
| ADG, lb | 1.78 | 1.91 | 1.74 | 1.83 | .07 | - | - | - |
| ADFI, lb | 7.22 | 6.98 | 6.96 | 6.50 | .15 | .05 | .06 | - |
| F/G | 4.05 | 3.66 | 3.99 | 3.55 | .02 | - | .03 | - |
| Overall (148 to 253 lb) | | | | | | | | |
| ADG, lb | 1.93 | 1.96 | 1.93 | 1.92 | .05 | - | - | - |
| ADFI, lb | 6.85 | 6.72 | 6.65 | 6.37 | .09 | .02 | .06 | - |
| F/G | 3.55 | 3.43 | 3.46 | 3.31 | .02 | - | .14 | - |
| Apparent digestibility, (d 23) % | | | | | | | | |
| DM | 83.7 | 87.6 | 86.7 | 87.6 | .8 | .10 | .02 | .10 |
| N | 80.4 | 85.5 | 85.1 | 85.9 | 1.2 | .07 | .04 | .11 |
| Carcass characteristics | | | | | | | | |
| Dressing percentage | 73.3 | 73.2 | 73.2 | 73.4 | 2 | - | - | - |
| Last rib fat thickness, in | .81 | .80 | .80 | .78 | .03 | - | - | - |
| Fat-free lean index, %[d] | 50.0 | 50.1 | 50.0 | 50.3 | .3 | - | - | - |
| Digesta viscosity, cps[e] | 5.0 | 3.9 | 5.1 | 4.4 | .7 | - | - | - |

[a]A total of 160 pigs (10 pigs/pen and four pens/treatment) with an avg initial BW of 148 lbs and an avg final BW of 253 lb.
[b]Contrasts were: 1) no enzyme vs enzyme; 2) 1,300 vs 600 microns; and 3) no enzyme vs enzyme × 1,300 vs 600 μm.
[c]Geometrical mean particle size.
[d]NPPC (1994) equation.
[e]A total of 40 pigs (five pigs/pen and two pens/treatment). Poise (cps) is equal to the viscosity of a fluid that would require a shearing force of 1 dyne to move a $cm^2$ of either layers of fluid 1 cm apart with a velocity of 1 cm/sec relative to the other layer with the space between the layers being filled with the fluid.
[f]Dashes indicate P>.15.

**Table 7. Effects of Enzyme Supplementation and Particle Size of Wheat-Based Diets on Stomach Morphology in Finishing Pigs (Exp. 2)[a]**

| | No Enzyme | | Enzyme | | | Contrasts[b] | | |
|---|---|---|---|---|---|---|---|---|
| Item | 1,300[c] | 600 | 1,300 | 600 | SE | 1 | 2 | 3 |
| Stomach keratinization | | | | | | | | |
| No. of observations | 38 | 36 | 34 | 37 | - | - | - | - |
| Normal | 38 | 24 | 33 | 25 | - | - | - | - |
| Mild | 0 | 12 | 1 | 7 | - | - | - | - |
| Moderate | 0 | 0 | 0 | 2 | - | - | - | - |
| Severe | 0 | 0 | 0 | 3 | - | - | - | - |
| Mean score[d] | 0 | .33 | .03 | .54 | .12 | NS[f] | .01 | NS |
| Stomach ulceration | | | | | | | | |
| No. of observations | 38 | 36 | 34 | 37 | - | - | - | - |
| Normal | 38 | 35 | 34 | 36 | - | - | - | - |
| Erosion | 0 | 0 | 0 | 1 | - | - | - | - |
| Ulcer | 0 | 1 | 0 | 0 | - | - | - | - |
| Severe ulcer | 0 | 0 | 0 | 0 | - | - | - | - |
| Mean score[e] | 0 | .06 | 0 | .03 | .04 | NS | NS | NS |

[a]A total of 160 pigs (10 pigs/pen and four pens/treatment) with an avg initial BW of 148 lbs and an avg final BW of 253 lb.
[b]Contrasts were: 1) no enzyme vs enzyme; 2) 1,300 vs 600 μm; and 3) no enzyme vs enzyme × 1,300 vs 600 mm.
[c]Geometrical mean particle size.
[d]Scoring system was: 0 = normal; 1 = mild; 2 = moderate; and 3 = severe keratosis (Cochran-Mantel-Haenszel statistic, row mean scores differ test; P<.01).
[e]Scoring system was: 0 = normal; 1 = erosion; 2 = ulcer; and 3 = severe ulcer (Cochran-Mantel-Haenszel statistic, row mean scores differ test; P>.17).
[f]Not significant (P>.15).

**Table 8. Effects of Enzyme Supplementation and Particle Size of Wheat-Based Diets on Growth Performance and Apparent Nutrient Digestibility in Finishing Pigs (Exp. 3)[a]**

| | No Enzyme | | Enzyme | | | Contrasts[b] | | |
|---|---|---|---|---|---|---|---|---|
| Item | 600[c] | 400 | 600 | 400 | SE | 1 | 2 | 3 |
| Growth performance | | | | | | | | |
| 139 to 198 lb | | | | | | | | |
| ADG, lb | 2.09 | 2.06 | 2.09 | 2.04 | .05 | -[f] | - | - |
| ADFI, lb | 6.39 | 6.08 | 6.54 | 5.99 | .09 | - | .01 | - |
| Feed/gain | 3.05 | 2.96 | 3.13 | 2.94 | .01 | - | .05 | - |
| 198 to 253 lb | | | | | | | | |
| ADG, lb | 1.87 | 1.96 | 2.00 | 2.01 | .04 | .04 | - | - |
| ADFI, lb | 6.43 | 6.43 | 6.61 | 6.52 | .11 | - | - | - |
| Feed/gain | 3.43 | 3.29 | 3.30 | 3.24 | .02 | - | - | - |
| Overall (139 to 253 lb) | | | | | | | | |
| ADG, lb | 1.98 | 2.01 | 2.05 | 2.02 | .03 | - | - | - |
| ADFI, lb | 6.41 | 6.26 | 6.59 | 6.26 | .09 | - | .04 | - |
| Feed/gain | 3.23 | 3.11 | 3.22 | 3.10 | .01 | - | .04 | - |
| Apparent digestibility, % | | | | | | | | |
| DM | 84.7 | 87.3 | 86.0 | 87.6 | .6 | .11 | .01 | - |
| N | 81.9 | 86.6 | 84.8 | 87.3 | 1.0 | - | .01 | - |
| Carcass characteristics | | | | | | | | |
| Dressing percentage | 74.0 | 74.2 | 74.0 | 74.0 | .1 | - | - | - |
| Last rib fat thickness, in | .86 | .84 | .87 | .81 | .01 | - | .06 | - |
| Fat-free lean index, %[d] | 49.6 | 49.8 | 49.5 | 50.0 | .2 | - | .06 | - |
| Digesta viscosity, cps[e] | 5.0 | 5.1 | 5.7 | 5.4 | .7 | - | - | - |

[a]A total of 160 pigs (10 pigs/pen and four pens/treatment) with an avg initial BW of 148 and an avg final BW of 253 lb.
[b]Contrasts were: 1) no enzyme vs enzyme; 2) 600 vs 400 mm; and 3) no enzyme vs enzyme × 600 vs 400 mm.
[c]Geometrical mean particle size.
[d]NPPC (1994) equation.
[e]A total of 40 pigs (five pigs/pen and two pens/treatment). Poise (cps) is equal to the viscosity of a fluid that would require a shearing force of 1 dyne to move a $cm^2$ of either layers of fluid 1 cm apart with a velocity of 1 cm per sec relative to the other layer with the space between the layers being filled with the fluid.
[f]Dashes indicate P>.15.

**Table 9. Effects of Enzyme Supplementation and Particle Size of Wheat-Based Diets on Stomach Morphology in Finishing Pigs (Exp. 3)[a]**

| | No Enzyme | | Enzyme | | | Contrasts[b] | | |
|---|---|---|---|---|---|---|---|---|
| Item | 600[c] | 400 | 600 | 400 | SE | 1 | 2 | 3 |
| Stomach keratinization | | | | | | | | |
| No. of observations | 38 | 35 | 33 | 36 | - | - | - | - |
| Normal | 26 | 4 | 24 | 2 | - | - | - | - |
| Mild | 6 | 12 | 7 | 18 | - | - | - | - |
| Moderate | 6 | 8 | 2 | 7 | - | - | - | - |
| Severe | 0 | 11 | 0 | 9 | - | - | - | - |
| Mean score[d] | .47 | 1.74 | .33 | 1.64 | .15 | NS[f] | .01 | NS |
| Stomach ulceration | | | | | | | | |
| No. of observations | 38 | 35 | 33 | 36 | - | - | - | - |
| Normal | 37 | 21 | 33 | 30 | - | - | - | - |
| Erosion | 1 | 10 | 0 | 2 | - | - | - | - |
| Ulcer | 0 | 2 | 0 | 4 | - | - | - | - |
| Severe ulcer | 0 | 2 | 0 | 0 | - | - | - | - |
| Mean score[e] | .03 | .57 | .0 | .28 | .09 | .13 | .01 | NS |

[a]A total of 160 pigs (10 pigs/pen and four pens/treatment) with an avg initial BW of 139 lbs and an avg final BW of 253 lb.
[b]Contrasts were: 1) no enzyme vs enzyme; 2) 600 vs 400 mm; and 3) no enzyme vs enzyme × 600 vs 400 mm.
[c]Geometrical mean particle size.
[d]Scoring system was: 0 = normal; 1 = mild; 2 = moderate; and 3 = severe ulceration (Cochran-Mantel-Haenszel statistic, row mean scores differ test; P<.01).
[e]Scoring system was: 0 = normal; 1 = erosion; 2 = ulcer; and 3 = severe ulcer (Cochran-Mantel-Haenszel statistic, row mean scores differ test; P<.01).
[f]Not significant (P>.15).

# EFFECTS OF SORGHUM ENDOSPERM HARDNESS AND PROCESSING ON GROWTH PERFORMANCE AND NUTRIENT DIGESTIBILITY IN PIGS AND BROILER CHICKS [1]

***H. Cao, J. D. Hancock, R. H. Hines, K. C. Behnke [2], J. S. Park, B. W. Senne, J. M. Jiang, J. R. Froetschner, and P. Sorrell***

## Summary

In nursery pigs, the greatest digestibilities of DM, N, and GE were observed with soft sorghum. In finishing pigs, no difference was observed in digestibility of nutrients among the sorghum genotypes. Chicks fed soft sorghum had better F/G than chicks fed medium and hard sorghum. Finally, thermal processing (steam flaking and extrusion) improved ADG and F/G and digestibilities of DM, N, and GE compared to grinding (coarse and fine).

(Key Words: Sorghum, Extrusion, Steam Flaking, Digestibility.)

## Introduction

In previous research from our laboratory, we demonstrated that processing can change the physical/chemical nature of sorghum with decreased particle size improving ADG, F/G, and digestibility of nutrients in pigs and chicks. Others have reported that softer endosperm tended to improve growth performance and nutrient digestibility in pigs. However, nothing is known about the interactions among endosperm characteristics and processing technologies that might optimize animal performance and nutrient digestibility. The experiments reported herein were designed with the objectives to determine the digestibility of various sorghum genotypes in pigs and to characterize any interactions among sorghum genotype and processing technologies in broiler chicks.

## Procedures

In Exp. 1, a total of 60 crossbred nursery pigs (14 d after weaning) was blocked by weight and allotted to pens based on sex and ancestry with five pigs/pen and three pens/treatment. The pigs were housed in an environmentally controlled building with wire-mesh floor during the 5-d experiment. A nipple waterer and self-feeder provided pigs ad libitum access to feed and water. Treatments were five sorghum genotypes grouped into soft (851111), medium (279 & PL-1), and hard (Segolane & 475) endosperm. All diets were formulated to .7% lysine, .7% Ca, and .6% P (Table 1). The ground sorghum (550 μm) was the only source of energy and protein in the diets. After a 3-d adjustment, fresh feces samples were collected twice per day for 2 d after a 3-d adjustment. The samples were dried and analyzed for concentrations of DM, CP, GE, and Cr.

For Exp.2, five finishing barrows (avg initial BW of 160 lb) were used in a 25-d metabolism trial with a 5×5 Latin square design. The pigs were housed in metabolism crates placed in an environmentally controlled building. The pigs were fed three times each day (7:00 am, 1:00 p.m., and 7:00 p.m.) with a feed allowance of $.05 \times BW^{0.9}$. After a 3-d adjustment period, fresh feces were collected twice a day for 2 d; dried; ground; and analyzed for DM, CP, GE, and Cr. The treatments were the same as in the nursery trial, except the diets were formulated to .6%

[1]Appreciation is extended to the Kansas State Board of Agriculture and the Kansas Sorghum Commission for funding this project.

[2]Department of Grain Science and Industry.

lysine, .55% Ca, and .5% P, with the sorghum ground to 550µm.

In Exp.3, 480 broiler chicks (avg initial BW of 98g) were used in a 21-d growth assay with 20 treatments (five genotypes × four processing methods). Chicks were housed (five chicks/pen and five pens/treatment) in brooder batteries and allowed ad libitum access to feed and water. Feces were collected during the last 2 d of the growth assay; dried; ground; and analyzed for DM, N, GE, and Cr. All diets were sorghum-SBM based and formulated to 1.32% lysine, 1.1% Ca, and 0.9% P. The sorghums used in the chick assay were cold (coarsely ground to 1000 µm and finely ground to 450 µm) and thermally (steam-flaking and extrusion) processed.

## Results and Discussion

Physical and chemical characteristics of the grain were typical for sorghum (Table 2) except for the distinctions made about kernel hardness. Energy required to coarsely grind, steam flake, and extrude the sorghums was similar, except that less energy was needed to finely grind the soft vs medium and hard sorghums. When fed to nursery pigs, the greatest (P<.08) digestibilities of DM, N, and GE were observed with soft sorghum (Table 4). A difference in digestibility of DM and GE among the medium and hard sorghums also was observed (P<.04), primarily because of the poor digestibility of genotype 279.

In finishing pigs, endosperm hardness did not affect nutrient digestibility (P>.1). However, there was a trend for lower digestibility of N with genotype 279 vs PL-1 (P<.07).

For broiler chicks (Table 5 and 6), those fed soft sorghum were more efficient than those fed the medium and hard sorghums (P<.03). Also, chicks fed steam-flaked sorghum had greater ADG (P<.001) and better F/G (P<.06) than chicks fed extruded sorghum. One notable interaction (P<.03) occurred among the sorghum genotypes and processing technologies, with the nutritional value of soft sorghum responding most to cold processing (grinding) and the nutritional value of the medium and hard sorghums responding best to thermal processing.

Digestibilities of DM, N, and GE were less (P<.001) for soft sorghum than for the medium and hard sorghums, especially when extruded. These results are problematic, especially in view of the better digestibility for soft sorghum in nursery pigs and the better growth performance of broiler chicks fed soft sorghum. Digestibilities of DM, N, and GE were improved (P<.02) by thermal processing (Table 6). Fine grinding was better than coarse grinding (P<.001), and steam flaking was better than extrusion (P<.02).

In conclusion, soft sorghum required less energy to process (especially fine grinding) than the medium and hard sorghums. Also, nutrient digestibility in nursery pigs and F/G for chicks was best with the soft sorghum. Of the processing technologies, fine grinding seemed to have the greatest promise with soft sorghum, but steam flaking was particularly useful for the medium and hard endosperm genotypes.

**Table 1. Compositions of Basal Diets with Exotic Sorghum Genotypes (Exps. 1, 2, and 3)[a]**

| Ingredient, % | Nursery (Exp.1) | Finisher (Exp. 2) | Chick (Exp. 3) |
|---|---|---|---|
| Sorghum | 94.40 | 96.30 | 53.30 |
| Soybean meal (46.5% CP) | -- | -- | 39.80 |
| Tallow | -- | -- | 1.00 |
| Monocalcium phosphate | 1.60 | 1.10 | 2.30 |
| Limestone | 1.01 | .85 | 1.50 |
| Salt | .35 | .30 | .50 |
| Vitamin premix | .25 | .15 | .23 |
| Mineral premix | .15 | .10 | .28 |
| Sow add pack | .03 | .05 | .26 |
| L-lysine HCl | .60 | .40 | -- |
| L-threonine | .20 | .16 | .10 |
| DL-methionine | .14 | .11 | .26 |
| L-tryptophan | .02 | .12 | -- |
| Copper sulfate | -- | -- | .06 |
| Antibiotics [b] | 1.00 | .125 | .25 |

[a]Nursery diets were formulated to .7% lysine, .7% Ca, and .6% P. Finisher diets were formulated to .6% lysine, .55% Ca, and .5% P. Chick diets were formulated to 1.32% lysine, 1.1% Ca, and .9% P.
[b]Nursery diets had 150g/ton apramycin, finisher diets had 40g/ton tylosin, and chick diets had 100g/ton chlortetracycline and .0125% amprolium.

**Table 2. Characteristics of Exotic Sorghum Genotypes**

| | Soft | Medium | | Hard | |
|---|---|---|---|---|---|
| Item | 851171 | 279 | PL-1 | 475 | Segolane |
| Physical traits | | | | | |
| Pericarp color | white | red | yellow | cream | cream |
| Endosperm color | white | white | yellow | white | white |
| Texture [a] | soft | medium | medium | hard | hard |
| Starch type [b] | normal | normal | normal | normal | normal |
| Chemical analyses | | | | | |
| Moisture, % | 9.7 | 10.2 | 10.6 | 10.8 | 10.9 |
| CP, % | 9.2 | 9.2 | 10.5 | 8.6 | 9.9 |
| Fat, % | 3.3 | 3.5 | 3.4 | 3.0 | 3.6 |
| Lysine, % | .28 | .23 | .23 | .21 | .21 |

[a]Texture was determined using the Single Kernel Characterization (SKC) method.
[b]Starch type was determined with the method of counting iodine stained granules with a haemocytometer.

**Table 3. Processing Energy Consumption of Sorghum Genotypes, kwh/t**

| | Soft | Medium | | Hard | | Processing |
|---|---|---|---|---|---|---|
| Item | 851171 | 279 | PL-1 | 475 | Segolane | Mean |
| Coarse [a] | 1.8 | 1.9 | 2.1 | 1.8 | 1.8 | 1.9 |
| Fine [b] | 1.9 | 3.2 | 2.9 | 2.6 | 2.9 | 2.7 |
| Flaked [c] | 3.0 | 3.5 | 3.0 | 3.3 | 2.7 | 3.1 |
| Extruded [d] | 68.2 | 76.6 | 67.5 | 71.8 | 70.0 | 70.8 |
| Genotype mean | 18.7 | 21.3 | 18.9 | 19.9 | 19.4 | |

[a]Ground in a roller mill to a mean particle size of 1,039 µm.
[b]Ground in a roller mill to a mean particle size of 440 µm.
[c]Steam flaked at 150°F.
[d]Extruded at 235°F.

**Table 4. Effects of Sorghum Geneotype on Nutrient Digestibility in Nursery and Finishing Pigs**

| | Soft | Medium | | Hard | | | Contrast[a] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | 851171 | 279 | PL-1 | Segolane | 475 | SE | 1 | 2 | 3 | 4 |
| Nursery, % [b] | | | | | | | | | | |
| DM | 84.3 | 75.0 | 84.8 | 83.1 | 83.9 | 1.2 | .08 | .03 | .001 | --[d] |
| N | 65.8 | 30.3 | 62.0 | 53.4 | 55.9 | 3.9 | .01 | -- | .001 | -- |
| GE | 80.5 | 68.0 | 81.3 | 78.8 | 79.9 | 1.7 | .07 | .04 | .001 | -- |
| Finishing, % [c] | | | | | | | | | | |
| DM | 90.2 | 89.5 | 90.1 | 90.5 | 90.0 | .5 | -- | -- | -- | -- |
| N | 78.0 | 73.2 | 78.6 | 76.7 | 77.1 | 1.8 | -- | -- | .07 | -- |
| GE | 90.0 | 89.0 | 89.5 | 90.2 | 89.6 | .6 | -- | -- | -- | -- |

[a]Contrast were: 1) soft vs others; 2) medium vs hard; 3) medium vs medium; and 4) hard vs hard.
[b]A total of 60 pigs (avg initial BW of 32 lb).
[c]Five finishing pigs (avg initial BW of 160 lb).
[d]Dashes indicated P>.1.

**Table 5. Effects of Sorghum Genotypes and Processing on Growth Performance in Chicks[a]**

| | Soft | Medium | | Hard | | Processing |
|---|---|---|---|---|---|---|
| Item | 851171 | 279 | PL-1 | 475 | Segolane | mean |
| ADG, g [b] | | | | | | |
| Coarse | 47.2 | 48.6 | 47.6 | 47.5 | 50.3 | 48.2 |
| Fine | 49.6 | 48.2 | 46.7 | 49.1 | 47.6 | 48.2 |
| Flaked | 48.7 | 51.7 | 49.9 | 49.6 | 49.3 | 49.8 |
| Extrude | 43.3 | 43.6 | 45.2 | 43.8 | 48.5 | 44.8 |
| Genotype mean | 47.4 | 48.3 | 47.3 | 47.5 | 48.9 | SE 1.4 |
| ADFI, g [c] | | | | | | |
| Coarse | 73.4 | 90.7 | 91.2 | 92.2 | 77.5 | 85.0 |
| Fine | 66.5 | 83.5 | 90.9 | 94.7 | 88.2 | 84.8 |
| Flaked | 77.6 | 75.6 | 84.4 | 74.3 | 71.9 | 76.4 |
| Extruded | 70.0 | 85.1 | 80.2 | 73.6 | 77.5 | 77.1 |
| Genotype mean | 72.0 | 83.7 | 87.2 | 83.7 | 78.8 | SE 6.4 |
| F/G [d] | | | | | | |
| Coarse | 1.53 | 1.87 | 1.91 | 1.79 | 1.50 | 1.70 |
| Fine | 1.33 | 1.71 | 1.77 | 1.92 | 1.85 | 1.69 |
| Flaked | 1.56 | 1.41 | 1.67 | 1.43 | 1.49 | 1.49 |
| Extruded | 1.61 | 1.92 | 1.75 | 1.64 | 1.52 | 1.67 |
| Genotype mean | 1.49 | 1.69 | 1.78 | 1.67 | 1.57 | SE 0.1 |

[a]A total of 480 chicks was used (five chicks/pen and five pen/trt) with an avg initial BW of 98 g. [b]Flake vs extruded (P<.001). [c]Soft vs others (P<.003); ground vs thermally processed (P<.01); soft vs others × ground vs thermally processed (P<.05). [d]Soft vs others (P<.03); flaked vs extruded (P<.06); soft vs others × ground vs thermally processed (P<.03).

**Table 6. Effects of Sorghum Genotypes and Processing on Nutrients Digestibility in Chicks[a]**

| | Soft | Medium | | Hard | | Processing |
|---|---|---|---|---|---|---|
| Item | 851171 | 279 | PL-1 | 475 | Segolane | Mean |
| DM, % [b] | | | | | | |
| Coarse | 67.5 | 71.2 | 67.9 | 72.9 | 71.3 | 70.2 |
| Fine | 69.5 | 73.7 | 74.8 | 73.0 | 73.4 | 72.9 |
| Flaked | 75.1 | 77.1 | 77.0 | 72.3 | 75.4 | 75.3 |
| Extrude | 68.9 | 76.0 | 74.5 | 74.6 | 75.8 | 74.1 |
| Genotype mean | | | | | | |
| CP, % [c] | | | | | | |
| Coarse | 58.8 | 60.2 | 56.6 | 64.0 | 59.5 | 59.8 |
| Fine | 59.4 | 63.0 | 69.4 | 66.3 | 61.6 | 63.0 |
| Flaked | 62.9 | 65.9 | 66.7 | 62.1 | 63.8 | 64.2 |
| Extruded | 58.2 | 65.2 | 63.8 | 63.4 | 63.9 | 63.0 |
| Genotype mean | | | | | | |
| GE, % [d] | | | | | | |
| Coarse | 73.7 | 75.7 | 74.2 | 77.4 | 76.7 | 75.5 |
| Fine | 77.1 | 78.1 | 80.2 | 78.7 | 78.4 | 78.5 |
| Flaked | 80.1 | 81.8 | 81.1 | 77.8 | 81.4 | 80.6 |
| Extruded | 74.9 | 79.7 | 80.0 | 79.1 | 79.9 | 78.8 |
| Genotype mean | 76.5 | 78.8 | 78.9 | 78.3 | 79.1 | SE .8 |

[a]A total of 480 chicks was used (five chicks/pen and 5 pen/trt) with an avg initial BW of 98 g. [b]Soft vs others (P<.001); ground vs thermally processed (P<.001); flaked vs extruded (P<.02); coarse vs fine (P<.001); soft vs others × flaked vs extruded. [c]Soft vs others (P<.001); ground vs thermally processed (P<.02); coarse vs fine (P<.001); soft vs others × coarse vs fine (P<.07). [d]Soft vs others (P<.001); ground vs thermally processed (P<.001); coarse vs fine (P<.001); flaked > extruded (P<.001); soft vs others × flaked vs extruded (P<.003).

# EFFECTS OF SORGHUM STARCH TYPE, ENDOSPERM HARDNESS, AND PROCESSING ON DIGESTIBILITY AND GROWTH PERFORMANCE IN FINISHING PIGS AND CHICKS [1]

*H. Cao, J. D. Hancock, R. H. Hines, K. C. Behnke [2], B. W. Senne, J. R. Froetschner [2], J. M. Jiang, and S. L. Johnston*

## Summary

In finishing pigs, waxy sorghum had lower digestibilities for DM and GE than the other genotypes. Also, the hard sorghums were more digestible (P<.06) than the medium hardness sorghum. In broiler chicks, the waxy sorghum was similar to the other genotypes for growth performance and nutrient digestibility. The soft sorghum was superior to the medium and hard genotypes for nutrient retention but not for growth performance. Fine grinding improved F/G and increased retention of nutrients and steam-flaked sorghum supported greater growth performance than extruded sorghum.

(Key Words: Sorghum, Processing, Chicks, Finishing Pigs.)

## Introduction

Previous research from our laboratory indicated that processing technologies and (or) endosperm hardness impact growth performance of chicks and pigs fed sorghums. Additionally, waxy sorghum is more susceptible to enzymes during digestion. However, little is known about potential interactions among endosperm type and processing technologies that might optimize nutrient digestibility and growth performance in swine and poultry. Therefore, experiments were designed to determine the effect of endosperm hardness and starch type on nutrient digestibility in pigs and to investigate the interactions among genotype and processing technology in broiler chicks.

## Procedures

Six sorghum genotypes were grouped into soft (851111), medium (279 & PL-1), hard (Segolane & 475), and waxy (739) categories. For the pig experiment, the sorghums were ground to a particle size of 550 μm. For the chick assay, the sorghums were (coarsely ground to 1,000 μm & finely ground to 450 μm) and thermally processed (steam-flaked at 150°F and extruded at 235°F).

For the pig experiment, five barrows (average initial BW of 142 lb) were used in a 5 × 5 Latin square design. The pigs were housed in metabolism cages placed in an environmentally controlled building (70°F). The pigs were fed three times per day (7:00 a.m., 1:00 p.m., and 7:00 p.m.). After a 3-d adjustment period, fresh feces were collected twice each day dried; ground; and analyzed for dry matter, crude protein, gross energy, and chromium. All diets were formulated to .6% lysine, .55% of Ca, and .50% P (Table 1), with the ground sorghums as the only source of energy and protein (Table 1).

In Exp.2, 600 broiler chicks (avg initial BW of 90 g) were used in a 21-d growth assay with 24 treatments (6 genotypes × 4 processing, and 5 pens/trt and 5 chicks/pen). The chicks were housed in brooder batteries and allowed ad libitum access to feed and

[1]Appreciation is extended to the Kansas State Board of Agriculture and the Kansas State Sorghum Commission for funding this project.

[2]Department of Grain Science and Industry.

water. Feces (with urine) were collected during the last 2 d of the growth assay; dried; ground; and analyzed for DM, CP, GE, and Cr to determine nutrient retention. All diets were sorghum-soybean meal-based with 1.0% tallow and formulated to 1.32% lysine, 1.1% Ca and 0.9% P (Table 1).

## Results and Discussion

Chemical analyses of the grains (Table 2) suggested that they were "normal" for moisture (8 to 12%) and crude protein (9 to 11%). However, notable differences occurred among the sorghums for texture and starch type, which allowed us to categorize the genotypes. Sorghum genotypes had less effect on energy consumption during processing than the processing technologies themselves, with thermal processing using more energy than grinding, and extrusion using more energy than steam flaking (Table 3). Energy consumption was similar among the genotypes, except for the low kwh/ton needed to coarsely and finely grind and steam flake Segolane. Also, waxy sorghum required the least energy to steam flake, suggesting a strong genotype × processing procedure interaction.

In finishing pigs, digestibilities of DM ($P<.01$) and GE ($P<.07$) were less for waxy sorghums than the other genotypes (Table 4). Also, the hard sorghums were more digestible ($P<.06$) than the medium hardness sorghums. Both of these effects were contrary to "conventional wisdom", which would support greater nutrient utilization from waxy and soft endosperm types.

In the broiler experiment (Table 5), no genotype effects on growth performance were observed. Chicks fed soft sorghum had greater ($P<.01$) retentions of DM, N, and GE compared to chicks fed medium and hard endosperm genotypes, whereas those fed hard sorghums had greater nutrient retention than those fed medium hardness sorghums ($P<.02$).

Grinding improved ADG ($P<.01$), ADFI ($P<.001$), and F/G ($P<.04$) when compared to thermal processing. However, thermal processing improved retention of DM, N, and GE ($P<.03$) compared to grinding. Retentions of DM, CP, and GE were improved with fine grinding versus coarse grinding ($P<.05$) and steam flaking versus extrusion ($P<.06$).

Interactions among genotypes and processing technologies were observed in feed efficiency. Soft sorghum responded more favorably ($P<.05$) to coarse grinding than to fine grinding compared to medium and hard types, and hard sorghum responded more favorably ($P<.01$) to flaking than to extrusion. As for nutrient retention, soft sorghum responded more favorably ($P<.01$) to thermal processing than to grinding compared to harder sorghums. Harder sorghum responded more favorably ($P<..01$) to flaking than to extrusion compared to medium sorghums. Waxy sorghums responded more positively to fine grinding ($P<.04$) and flaking ($P<.06$) than to coarse grinding and extrusion compared to nonwaxy sorghum.

In conclusion, retention of DM and GE for finishing pigs was greater with hard endosperm than soft and waxy sorghums. Feed efficiency was greatest in chicks fed the hard sorghum and steam-flaked treatments. Retentions of DM, N, and ME were greatest for chicks fed soft genotypes and thermally processed sorghums. However, within thermal processing, waxy endosperm sorghum responded more favorably to steam flaking and less favorably to extrusion, whereas soft and medium sorghums showed the opposite response.

**Table 1. Compositions of Basal Diets with Exotic Sorghum Genotypes (Exps. 1 and 2)[a]**

| Ingredient, % | Finisher (Exp. 1) | Chick (Exp. 2) |
|---|---|---|
| Sorghum | 96.30 | 53.30 |
| Soybean meal (46.5 % CP) | -- | 39.80 |
| Tallow | -- | 1.00 |
| Monocalcium phosphate | 1.10 | 2.30 |
| Limestone | .85 | 1.50 |
| Salt | .30 | .50 |
| Lysine HCl | .40 | -- |
| Threonine | .16 | .10 |
| D, L-methionine | .11 | .26 |
| Tryptophan | .12 | -- |
| Vitamin premix | .15 | .23 |
| Mineral premix | .10 | .28 |
| Sow add pack | .05 | .26 |
| Chromium | .25 | .20 |
| Copper sulfate | -- | .06 |
| Antibiotics [b] | .125 | .25 |

[a]Finisher diets were formulated to .6% lysine, .55% Ca, and .5% P. Chick diets were formulate to 1.32% lysine, 1.1% Ca, and .9% P.
[b]Finisher diets had 40 g/ton tylosin; chick diets had 100 g/ton chlortetracycline and .0125% amprolium.

**Table 2. Characteristics of Exotic Sorghum Genotypes**

| | Soft | Medium | | Hard | | Waxy |
|---|---|---|---|---|---|---|
| Item | 851171 | 279 | PL-1 | 475 | Segolane | 739 |
| Physical traits | | | | | | |
| Pericap color | white | red | yellow | cream | cream | cream |
| Endosperm color | white | white | yellow | white | white | white |
| Texture [a] | soft | medium | medium | hard | hard | soft |
| Starch type [b] | normal | normal | normal | normal | normal | waxy |
| Chemical analyses | | | | | | |
| Unprocessed | | | | | | |
| Moisture, % | 10.8 | 8.5 | 104 | 9.5 | 10.6 | 11.8 |
| CP, % | 11.2 | 11.3 | 10.8 | 10.1 | 10.0 | 8.8 |
| Extruded | | | | | | |
| Moisture, % | 4.4 | 4.5 | 4.8 | 5.5 | 4.7 | 5.3 |
| CP, % | 12.6 | 12.2 | 12.7 | 10.7 | 11.5 | 10.8 |
| Steam-flaked | | | | | | |
| Moisture, % | 8.9 | 8.6 | 11.1 | 9.9 | 8.8 | 11.9 |
| CP, % | 10.5 | 11.1 | 10.5 | 10.1 | 10.0 | 10.3 |

[a]Texture was determined using the Single Kernel Characterization (SKC) method.
[b]Starch type was determined by visual appraisal.

**Table 3. Processing Energy Consumption of Sorghum Genotypes, kwh/t**

| | Soft | Medium | | Hard | | Waxy | Processing |
|---|---|---|---|---|---|---|---|
| Item | 851171 | 279 | PL-1 | 475 | Segolane | 739 | Mean |
| Coarse [a] | 11.9 | 13.9 | 10.8 | 10.8 | 8.3 | 13.6 | 11.5 |
| Fine [b] | 10.3 | 12.1 | 12.3 | 8.2 | 8.2 | 15.4 | 11.1 |
| Flaked [c] | 60.4 | 57.3 | 50.6 | 50.6 | 40.8 | 36.1 | 49.3 |
| Extruded [d] | 76.0 | 74.2 | 72.5 | 72.1 | 76.4 | 66.6 | 70.2 |
| Genotype mean | 39.7 | 39.4 | 36.5 | 35.4 | 33.4 | 32.9 | |

[a]Ground in a roller mill to a mean particle size of 1,039 µm.

[b]Ground in a roller mill to a mean particle size of 440 µm.

[c]Steam-flaked at 150°F.

[d]Extruded at 235°F.

**Table 4. Effect of Sorghum Genotype on Nutrient Digestibility in Finishing Pigs[a]**

| Digestibility, | Soft | Medium | Hard | | Waxy | | Contrast [b] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| % | 851171 | PL-1 | Segolane | 475 | 739 | SE | 1 | 2 | 3 | 4 |
| DM | 83.8 | 84.3 | 86.5 | 87.2 | 82.2 | .9 | --[c] | .06 | -- | .01 |
| N | 69.7 | 65.6 | 67.0 | 68.3 | 69.5 | 2.3 | -- | -- | -- | -- |
| GE | 83.3 | 83.4 | 85.8 | 85.6 | 82.5 | .9 | -- | .06 | -- | .07 |

[a]Five finishers were used (avg initial BW of 160 lb).

[b]Contrast were: 1) soft vs medium & hard; 2) medium vs hard; 3) hard vs hard; and 4) waxy vs others.

[c]Dashes indicated P>.1.

**Table 5. Effects of Sorghum Genotypes and Processing on Growth Performance in Chicks[a]**

| | Soft | Medium | | Hard | | Waxy | Processing |
|---|---|---|---|---|---|---|---|
| Item | 851171 | 279 | PL-1 | 475 | Segolane | 739 | Mean |
| ADG, g [b] | | | | | | | |
| Coarse | 39.1 | 35.7 | 40.2 | 37.7 | 39.4 | 38.8 | 38.5 |
| Fine | 37.7 | 38.4 | 37.9 | 39.5 | 39.0 | 39.1 | 38.6 |
| Flaked | 37.8 | 37.7 | 33.1 | 39.1 | 39.7 | 37.9 | 37.4 |
| Extrude | 33.1 | 34.2 | 36.0 | 35.6 | 29.0 | 34.3 | 33.9 |
| Genotype mean | 36.9 | 36.5 | 36.8 | 38.0 | 36.9 | 37.5 | SE 1.1 |
| ADFI, g [c] | | | | | | | |
| Coarse | 56.3 | 57.2 | 63.0 | 57.3 | 60.6 | 56.8 | 58.5 |
| Fine | 57.0 | 56.1 | 53.5 | 59.2 | 55.4 | 58.2 | 56.6 |
| Flaked | 58.5 | 57.8 | 51.1 | 58.3 | 55.0 | 58.0 | 56.4 |
| Extruded | 52.3 | 50.1 | 51.4 | 57.5 | 49.0 | 56.6 | 53.0 |
| Genotype mean | 56.1 | 55.2 | 54.7 | 58.1 | 55.3 | 57.4 | SE 2.1 |
| F/G [d] | | | | | | | |
| Coarse | 1.43 | 1.46 | 1.56 | 1.52 | 1.54 | 1.47 | 1.52 |
| Fine | 1.51 | 1.53 | 1.41 | 1.50 | 1.42 | 1.49 | 1.46 |
| Flaked | 1.55 | 1.46 | 1.54 | 1.49 | 1.40 | 1.54 | 1.50 |
| Extruded | 1.58 | 1.56 | 1.42 | 1.62 | 1.70 | 1.65 | 1.56 |
| Genotype mean | 1.51 | 1.51 | 1.48 | 1.53 | 1.50 | 1.53 | SE .02 |

[a]A total of 600 chicks was used (five chicks/pen and five pen/trt) with an avg initial BW of 90 g. [b]Hard vs hard (P<.06); ground vs thermally processed (P<.01); flake vs extruded (P < .01). [c]Ground vs thermally processed (P<.001); flake vs extruded (P<.01); 475 vs Segolane × ground vs thermally processed (P<.08); medium vs hard × flake vs extrusion (P<.01). [d]Ground vs thermally processed (P<.04); coarse vs fine (P<.07); flaked vs extruded (P<.07); soft vs medium & hard × coarse vs fine ground (P<.05); medium vs hard × flaked vs extruded (P<.001).

**Table 6. Effects of Sorghum Genotypes and Processing on Nutrient Retention in Chicks[a]**

| | Soft | Medium | | Hard | | Waxy | Processing |
|---|---|---|---|---|---|---|---|
| Item [e] | 851171 | 279 | PL-1 | 475 | Segolane | 739 | Mean |
| DM, % [b] | | | | | | | |
| Coarse | 73.7 | 73.9 | 73.0 | 75.3 | 76.9 | 71.4 | 74.0 |
| Fine | 75.5 | 78.7 | 77.2 | 75.0 | 76.9 | 77.5 | 77.0 |
| Flaked | 80.2 | 67.2 | 75.6 | 81.1 | 71.3 | 79.5 | 76.1 |
| Extrude | 80.3 | 72.7 | 78.1 | 75.8 | 80.1 | 77.8 | 77.4 |
| Genotype mean | 77.7 | 73.5 | 76.0 | 76.8 | 76.1 | 76.6 | SE 1.1 |
| N, % [c] | | | | | | | |
| Coarse | 58.4 | 57.79 | 56.2 | 59.9 | 62.5 | 53.73 | 58.1 |
| Fine | 61.7 | 63.2 | 62.4 | 57.4 | 59.79 | 63.1 | 61.2 |
| Flaked | 67.4 | 42.4 | 58.5 | 69.1 | 46.7 | 64.7 | 58.7 |
| Extruded | 71.4 | 54.6 | 60.8 | 57.1 | 67.1 | 62.3 | 62.0 |
| Genotype mean | 64.7 | 55.1 | 59.5 | 60.9 | 58.6 | 61.0 | SE 2.3 |
| GE, % [d] | | | | | | | |
| Coarse | 77.2 | 78.4 | 76.2 | 78.5 | 80.9 | 74.8 | 77.7 |
| Fine | 80.1 | 82.3 | 81.3 | 79.0 | 80.9 | 81.0 | 80.8 |
| Flaked | 83.8 | 73.2 | 80.0 | 84.8 | 76.4 | 83.3 | 80.5 |
| Extruded | 84.4 | 77.6 | 82.0 | 79.6 | 83.6 | 81.7 | 81.4 |
| Genotype mean | 81.4 | 78.1 | 79.9 | 80.5 | 80.3 | 80.2 | SE 1.0 |

[a]A total of 600 chicks was used (five chicks/pen and five pen/trt) with an avg initial BW of 90 g.
[b]Soft vs medium & hard (P<.01); medium vs hard (P<.01); ground vs thermally processed (P<.03), coarse vs fine (P<.001); flaked vs extruded (P<.02); soft vs medium & hard ×thermal processed (P<.001); ); medium vs hard × ground vs thermally processing (P < .01); medium vs hard × coarse vs fine ground (P<.01).
[c]Soft vs medium & hard (P<.001); coarse vs fine (P<.05); flaked vs extruded (P<.06); waxy vs others × ground vs thermally processing (P<.05); waxy vs others × coarse vs fine ground (P<. 09); waxy vs others × flaked and extruded (P<.04).
[d]Soft vs medium & hard (P<.01); medium vs hard (P<.01); ground vs thermally processed (P<.001), coarse vs fine (P<.001); flaked vs extruded (P<.08), soft vs medium & hard × ground vs thermal processed (P<.001); medium vs hard × ground vs thermally processing (P<.001); medium vs hard × coarse vs fine ground (P<.03); waxy vs others × ground vs thermally processing (P<.06); waxy vs others × coarse vs fine ground (P<. 04); waxy vs others × flaked and extruded (P<.01).

*Swine Day 1998*

# EFFECTS OF PARTICLE SIZE AND MIXING TIME ON UNIFORMITY AND SEGREGATION IN PIG DIETS

*N. Amornthewaphat [1], K. C. Behnke [1], and J. D. Hancock*

## Summary

Diet uniformity, as represented by the coefficient of variation (CV), improved as mixing time was increased from 15 to 120 seconds and(or) corn particle size was decreased from 1,200 to 400 µm. Segregation occurred during free-fall, and the coarser particle sizes resulted in greater segregation than the finer particle sizes. Thus, reducing particle size of the cereal grain in swine diets not only improves efficiency of growth (as demonstrated in numerous KSU Swine Day Reports) but also decreases mix time needed for adequate blending and the likelihood of segregation during handling, storage, and delivery of diets to feeders.

(Key Words: Mixing, Particle Size, Diet Uniformity.)

## Introduction

Mixing is an important operation in feed manufacturing. Mixing diets for broilers and nursery pigs to CVs of 10 to 20%, and diets for finishing pigs to CVs less than 50%, will increase growth performance. Obvious management/maintenance problems, such as inadequate mix time and worn mixers, will decrease mix uniformity. However, even with what is assumed to be adequate mix time and well maintained equipment, diet characteristic still are thought to have an effect on mix uniformity. Therefore, the experiments reported herein were designed to address the effects of particle size and mixing time on diet uniformity and segregation.

## Procedures

To achieve desired particle size, corn was ground in a hammermill equipped with screens having openings of 1/2, 3/16, 9/64, and 1/64 inch. The corn was used in a diet formulated to .8% lysine, .6% Ca, and .5% P. All other nutrients met or exceeded NRC (1988) recommendations. Treatments were arranged as a 4× 4 factorial with corn ground to 1,200, 800, 600, and 400 µm and mix times of 15, 30, 60, and 120 seconds.

The experimental design was a split-plot with three, 100-lb batches made for each particle size treatment. A batch of each particle size was the experimental unit for the whole plot. These particle sizes (whole plot) batches then were divided for the mix time treatments.

The diets were mixed in a double-ribbon mixer. The major ingredients (corn and soybean meal) were weighed and placed in the center of the mixer and minor ingredients (monocalcium phosphate, limestone, vitamins, and minerals) were weighed (in order of decreasing percentage of the diet) and placed on top of the major ingredients. Salt (.15%) and blue (Microtracer® RF-blue) dyed particles (.01%) were added as the last ingredients on top of the diet. The mixer was stopped when a targeted mix time was reached, and 10 samples were taken at various sites throughout the mixer. The CVs were determined for each batch of feed with salt and blue particles used as markers.

[1]Department of Grain Science and Industry.

**Table 1. Diet Composition[a]**

| Ingredients | % |
|---|---|
| Corn | 73.95 |
| Soybean meal (46.5% CP) | 23.52 |
| Monocalcium phosphate | 1.06 |
| Limestone | .92 |
| Salt | .15 |
| Vitamin premix | .25 |
| Trace mineral premix | .15 |

[a]Formulated to .8% lysine, .6% Ca, and .5% P.

The data were analyzed as a split-plot design with polynomial regression (coefficient for unequally spaced treatments) used to characterize the shape of the response curve and to identify interactions among particle sizes and mix times. The data were analyzed as a completely randomized design.

To determine the effects of corn particle size on segregation of uniformly mixed feed, batches from the previous experiment were dumped through a 20-ft tall, 6-inch-diameter pipe into a single-hole wet/dry feeder (Crystal Spring®). Ten out of the 12 samples were taken randomly from the feeder. These samples were analyzed for salt and blue particles, and CVs were calculated.

## Results and Discussion

The geometric mean particle sizes ($d_{gw}$) of the corn for each treatment (1,200, 825, 597, and 475 µm) were close to the targeted particle sizes of 1200, 800, 600, and 400 µm (Table 2). Uniformity of particle size ($s_{gw}$) decreased from 2.41 to 1.81 as $d_{gw}$ was decreased from 1,200 to 400 µm. We have reported previously that as mean particle size was reduced, uniformity of particle size improved. Thus, fine grinding is one method of improving particle size uniformity.

The CVs for both analytical procedures (salt and blue particles) decreased dramatically (Figures 1 and 2) as mix time was increased from 15 to 30 seconds and improved little as mix time was increased further to 60 and 120 seconds (quadratic effects, P<.001). Also, larger corn particles yielded more variable CVs than finer corn, especially when mixing time was very short (linear effects, P<.001). However, a strong interaction of particle size × mix time (P<.001) occurred, with larger corn particle size requiring more mix time to achieve uniformity. Indeed, mix time needed for the 400 to 600 µm treatments to reach CVs of 15 to 20% or less was 15 seconds. For the 800 to 1,200 µm treatments, roughly twice as much mix time (25 to 30 seconds) was needed to reach CVs of 15 to 20% or less.

For the segregation experiment, CVs (Table 3) for both analytical procedures (salt and blue particles) increased after free fall (P<.05). Larger corn particle sizes caused greater segregation. However, even the 1,200 µm corn did not result in CVs that would cause concern (i.e., above 15 to 20%).

In conclusion, diet uniformity improved as mixing time was increased and corn particle size was decreased. Segregation occurred during free fall and was greater with larger particle sizes. Thus, minimizing particle size is not only important for optimizing growth performance of pigs but also for enhancing feed manufacturing processes.

**Table 2. Characteristics of the Corn**

| | Particle Size, µm | | | |
|---|---|---|---|---|
| Item | 1,200 | 800 | 600 | 400 |
| Hammermill screen, in | 1/2 | 1/4 | 9/64 | 1/16 |
| Grain characteristics | | | | |
| $d_{gw,}$ µm[a] | 1,200 | 825 | 597 | 475 |
| $s_{gw,}$ µm[a] | 2.41 | 2.29 | 1.93 | 1.81 |

[a]Geometric mean particle size ($d_{gw}$) and log normal standard deviation ($s_{gw}$).

**Table 3. Change in CVs for Salt and Blue Particles with Free Fall**

| Item | 1200 | 800 | 600 | 400 | SE |
|---|---|---|---|---|---|
| CV for salt | | | | | .45 |
| Before | 7.01 | 8.45 | 7.56 | 5.22 | |
| After | 12.13 | 9.43 | 8.92 | 8.07 | |
| Change | 5.12 | .98 | 1.36 | 2.85 | |
| CV for RF-blue | | | | | .42 |
| Before | 6.69 | 4.27 | 2.44 | 4.07 | |
| After | 10.99 | 9.02 | 6.93 | 5.29 | |
| Change | 4.30 | 4.75 | 4.49 | 1.22 | |

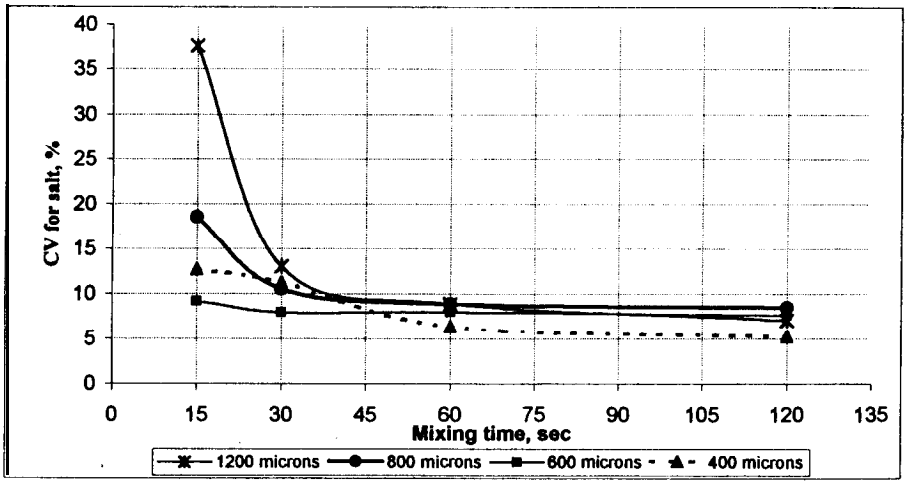



**Figure 1. Effect of Particle Size and Mix Time on Diet Uniformity (Salt). Linear (P<.001) and quadratic (P<.07) effects of particle size, linear and quadratic effects of mix time (P<.001), and the particle X mix time interaction (P<.001) were observed.**

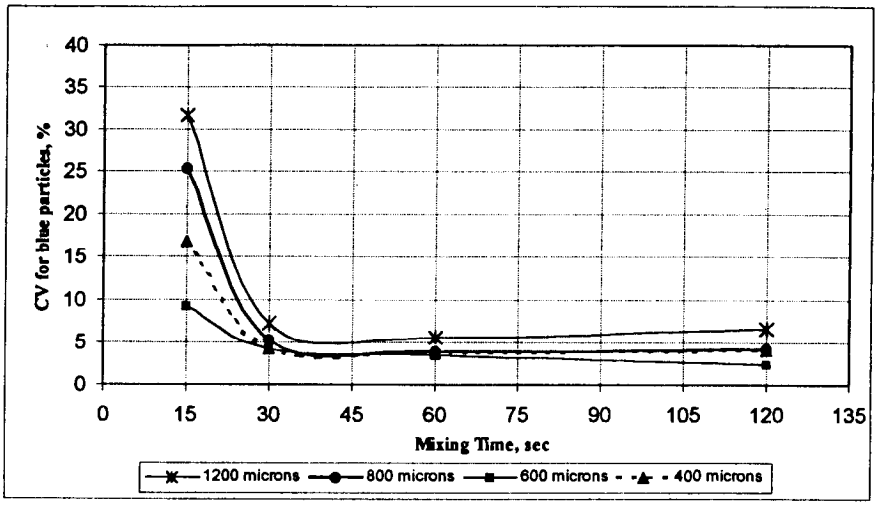



**Figure 2. Effect of Particle Size and Mix Time on Diet Uniformity (Blue Particle). Linear (P<.001) and quadratic (P<.02) effects of particle size, linear and quadratic effects of mix time (P<.001) the particle X mix time interaction (P<.001) were observed.**

**ACKNOWLEDGEMENTS**

Appreciation is expressed to these organizations for assisting with swine research at Kansas State University:

ADM Animal Health, Des Moines, IA
American Livestock Equipment, Clay Center, KS
American Proteins Corporation, Ames, IA
American Soybean Association, St. Louis, MO
American Veterinary Medical Association, Schaumburg, IL
Archer Daniels Midland Company, Decatur, IL
BASF, Parsippany, NJ
BioKyowa, Inc., St. Louis, MO
Church and Dwight Co, Inc., Princeton, NJ
Cryovac Division, W.R. Grace & Co., Duncan, SC
Custom Ag Products, Beloit, KS
Daiichi Pharmaceutical Company Ltd., Tokyo, Japan
Degussa Inc., Alandale, NJ
Dupont Quality Grains, Des Moines, IA
Earthrise Co., Tollhouse, CA
Eichman Farms, St. George, KS
Elanco Products Company, Indianapolis, IN
Excel Corp., Wichita, KS
Farmland Industries, Kansas City, MO
Feed Products and Service Company, St. Louis, MO
Finn Feeds Int., Schaumburg, IL
Foremost Farms, USA, Sauk City, WI
Global Ventures, Pipestone, MN
Henry's LTD, Longford, KS
Hercules Inc., Wilmington, DE
Hoffman-LaRoche, Inc., Nutley, NJ
International Ingredients Co., St. Louis, MO
Iowa Limestone Co., Des Moines, IA
Kansas Pork Producers Council, Manhattan, KS
Kansas Sorghum Commission, Topeka, KS
Kansas Soybean Commission, Topeka, KS
Kansas State Board of Agriculture, Topeka, KS
Keesecker Ag-business, Washington, KS
Kemin Industries, Des Moines, IA
Key Milling, Clay Center, KS
Land O' Lakes, Fort Dodge, IA
Livestock and Meat Industry Council, Manhattan, KS
Lonza, Inc., Fair Lawn, NJ
Loveland Industries, Hereford, TX
Luzenac America, Englewood, CO
M-TEK Inc., Elgin, IL
McCullough & Co., Kansas City, MO
Midwest Grain Products, Atchison, KS
Monsanto Ag. Co. St. Louis, MO
National Pork Producers Council, Des Moines, IA
NC+ Hybrids, Colwich, KS
Novus International Inc., St. Louis, MO
Nutri-Quest, Chesterfield, MO
Omega Proteins, Mandeville, LA
Pfizer, Inc., Lees Summit, MO
Pharmanutrients Inc., Lake Bluff, IL
Pig Improvement Co., Franklin, KY
Pioneer Hi-Bred Int., Manhattan, KS
Pipestone System, Pipestone, MN
Pork Packers International, Downs, KS
Premium Pork Inc., Kensington, KS
Prince Agric Products, Inc., Quincy, IL
SAF Products, Minneapolis, MN
Seaboard Farms, Inc., Gymon, OK
Triple "F" Products, Des Moines, IA
Tyson Foods, Springdale, AR
U.S. Poultry & Egg Association, Tucker, GA
United States Department of Agriculture, Science and Education, Washington, DC
Wenger Manufacturing, Inc., Sabetha, KS
Zapata Proteins, Mandeville, LA
Zen-Oh Group, Osaka, Japan
Zin-Pro Inc., Eden Prairie, MN

We especially appreciate the assistance and dedication of Rob Musser, Mark Nelson, Lyle Figgy, Robert Beckley, Eldo Heller, and Theresa Rathbun.

We gratefully acknowledge Eileen Schofield for editorial assistance, Valerie Stillwell for word processing, and Fred Anderson for cover design for this publication.

**Swine Industry Day Committee**

Jim Nelssen, Chairman
Duane Davis
Steve Dritz
Bob Goodband
Mike Tokach
Joe Hancock
Bob Hines

Contribution No. 99-120-S from the Kansas Agricultural Experiment Station.

Kansas State University Agricultural Experiment Station and Cooperative Extension Service, Manhattan 66506

SRP 819 October 1998



2.5 M