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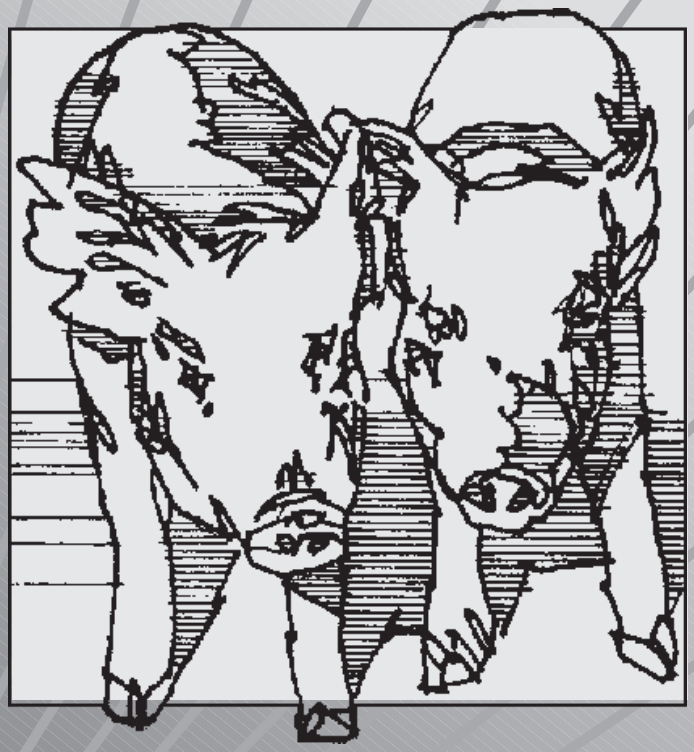

SWINE DAY 2003

Report of Progress 920

FOREWORD

It is with great pleasure that we present to you the 2003 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, 2003 Swine Day Report of Progress,

Bob Goodband Mike Tokach Steve Dritz Joel DeRouchey

ABBREVIATIONS USED IN THIS REPORT

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

NCR, 1998. Nutrient Requirements of Swine. 10th Ed. National Academy Press, Washington, DC.

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, 1,500 mg; pantothenic acid, 5,000 mg; niacin, 9,000 mg; and vitamin B_{12}, 7 mg.

Sow add pack: each lb of premix contains choline, 100,000 mg; biotin, 40 mg; folic acid, 300 mg; and pyridoxine, 900 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

Gestation, Breeding, and Farrowing Management

Effects of L-Carnitine on Fetal Growth and the Insulin-Like Growth Factor System in Pigs 1

Influence of Carnichrome® on Energy Balance of Gestating Sows 7

Comparison of Three Methods of Feeding Sows in Gestation and the Subsequent Effects on Lactation Performance 19

Pelleted Diets for Lactating Sows 33

Particle Size of Corn in Lactation Diets for Mixed-Parity Sows 36

Nursery Management

Effects of Increasing Dietary Lysine in Transition Diets on Nursery Pig Growth Performance 39

Effects of Increasing Dietary Lysine in Phase II Diets (15- to 25-lb) on Nursery Pig Growth Performance 43

Effects of Increasing Crystalline Amino Acids and the Subsequent Change in Diet Net Energy on Growing Pig Performance 47

Effects of Increasing Crystalline Lysine and Dietary Fat on Finishing Pig Growth Performance 56

The Optimal True Ileal Digestible Lysine and Threonine Requirement for Nursery Pigs Between 25 and 55 lb 61

The Optimal True Ileal Digestible Lysine Requirement for 22 to 45 lb Pigs 67

The Influence of Dietary Fat Level and Crystalline Amino Acid Additions on Growth Performance of 25- to 50-lb Pigs 71

Effects of Diet Complexity and Replacement of Soybean Meal on Growth Performance of Weanling Pigs 77

Evaluation of Different Soy Protein Concentrate Sources on Growth Performance of Weanling Pigs 81

Effects of Extruded-Expelled Soybean Meal and Solvent Extracted Soybean Meal Level of Growth Performance of Weanling Pigs 90

The Effects of Poultry Meal and Fishmeal on Growth Performance of Weanling Pigs 97

The Effects of Poultry Meal Source on Growth Performance of Weanling Pigs 102

Comparison of Antimicrobial Alternatives in Irradiated Diets for Nursery Pigs 106

Comparison of Antimicrobial Alternatives in Diets for Nursery Pigs 111

Comparison of Antibiotics and Antimicrobial Alternatives on Growth Performance of Weanling Pigs in a Commercial Environment 115

Comparison of Antibiotics on Growth Performance of Weanling Pigs in a Commercial Environment 119

Effects of Prebiotic, Inulin, and a Direct Fed Microbial on Growth Performance of Weanling Pigs.....123

Mannanoligosaccharides in Diets for Nursery Pigs 128

Effects of a Heat-Stable Yeast Product and Antibiotics in Diets for Nursery Pigs 132

Effects of BioPlus 2B and Levucell SB on Weanling Pig Growth Performance and Fecal Shedding in Response to Oral Challenge with *Salmonella* Serovar Tryphimurium 136

Corn Particle Size and Pelleting Influence on Growth Performance, Fecal Shedding, and Lymph Node Infection Rates of *Salmonella entericas* Serovar Tryphimurium.....141

Evaluation of Hemicell® on Growth Performance of Late Nursery Pigs 146

Growing-Finishing Management

Effects of Increasing Crystalline Lysine with Other Amino Acids on Growth Performance of 85- to 135-lb Gilts.....150

Added Fat in Diets for Pigs in Early and Late Finishing 155

Effect of Added Fat on Performance of Growing-Finishing Pigs in Commercial Conditions 159

Dietary Energy Density and Growing-Finishing Pig Performance and Profitability.....164

Effects of Increasing Ca:P Ratio in Diets Containing Phytase on Finishing Pig Growth Performance 171

Effects of Corn Source and Fat Level on Growth Performance of Grow-Finish Pigs Reared in a Commercial Facility.....176

Use of Dried Distiller's Grains with Solubles for Swine Diets 185

The Effects of Reducing Dietary Crude Protein and/or Adding Chicory on Composition and Odor of Stored Swine Manure.....193

Particle Size, Mill Type, and Added Fat Influence Flow Ability of Ground Corn.....203

The Influence of Chop Location on Pork Loin Quality 209

Index of Key Words 215

Acknowledgements 216

Livestock and Meat Industry Council 217

BIOLOGICAL VARIABILITY AND CHANCES OF ERROR

Variability among individual animals in an experiment leads to problems in interpreting the results. Animals on treatment X may have higher average daily gains than those on treatment Y, but variability within treatments may indicate that the differences in production between X and Y were not the result of the treatment alone. Statistical analysis allows us to calculate the probability that such differences are from treatment rather than from chance.

In some of the articles herein, you will see the notation "$P<0.05$." That means the probability of the differences resulting from chance is less than 5%. If two averages are said to be "significantly different," the probability is less than 5% that the difference is from chance or the probability exceeds 95% that the difference resulted from the treatments applied.

Some papers report correlations or measures of the relationship between traits. The relationship may be positive (both traits tend to get larger or smaller together) or negative (as one trait gets larger, the other gets smaller). A perfect correlation is one (+1 or -1). If there is no relationship, the correlation is zero.

In other papers, you may see an average given as 2.5 ± 0.1. The 2.5 is the average; 0.1 is the "standard error." The standard error is calculated to be 68% certain that the real average (with unlimited number of animals) would fall within one standard error from the average, in this case between 2.4 and 2.6.

Many animals per treatment, replicating treatments several times, and using uniform animals increase the probability of finding real differences when they exist. Statistical analysis allows more valid interpretation of the results, regardless of the number of animals. In all the research reported herein, statistical analyses are included to increase the confidence you can place in the results.

Swine Day 2003

EFFECTS OF L-CARNITINE ON FETAL GROWTH AND THE INSULIN-LIKE GROWTH FACTOR SYSTEM IN PIGS[1]

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Summary

Twelve sows were used to examine the effects of feeding L-carnitine from artificial insemination to mid-gestation on maternal circulating IGF-I and carnitine concentrations and fetal growth. Supplementing L-carnitine did not influence the serum concentration of IGF-I. However, sows that were fed carnitine had increased circulating plasma free carnitine. Litters from sows fed L-carnitine were heavier and had more fetuses. The increase in litter fetus number was not detrimental to other growth traits such as individual fetal weight or crown to rump length. Our study suggests that feeding L-carnitine to gestating sows is beneficial for fetal growth and development.

(Key Words: Sows, Carnitine, Insulin-like Growth Factor)

Introduction

L-carnitine is a water-soluble amine that is naturally synthesized in liver, kidney, and brain. This compound plays an important role in lipid metabolism where it serves as a co-factor in mitochondrial transport and oxidation of long-chain fatty acids. Carnitine has also been found to regulate carbohydrate metabolism. Fatty acids and carbohydrates are essential nutrients for the development of tissue, including skeletal muscle in mammals.

Insulin-like growth factors (IGF) –I and –II are proteins that have potent proliferative and differentiation-promoting effects on cultured muscle cells, and the interactions of these growth factors with muscle cells play a significant role in regulating growth and differentiation of muscle tissues *in vivo*.

Previous research has shown that feeding L-carnitine to gestating sows increased circulating IGF-I and free carnitine at mid-gestation. Additionally, supplemented L-carnitine fed to sows during gestation resulted in piglets with a larger cross-sectional area of semitendinosus muscle. These data suggest that feeding L-carnitine to gestating sows will positively affect muscle growth and development in subsequent offspring. However, the exact mechanism of L-carnitine's affect on muscle growth has not been determined. Therefore the objectives of this experiment were to: 1) further evaluate the circulating concentration of IGF-I and carnitine in sows fed a diet with or without carnitine and 2) evaluate fetal growth characteristics of fetal

[1]The authors would like to thank Lonza, Inc., Fair Lawn, New Jersey, for their financial support.
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pigs at mid-gestation from sows fed L-carnitine as compared to control-fed sows.

Procedures

All animal procedures were reviewed and approved by the Kansas State University Animal Care and Use Committee. Twelve fourth-parity sows (PIC, Franklin, Kentucky; C 22 sows; BW = 552.6 lb) were inseminated (PIC; 327 MQ) artificially 12, 24, and 36 hours after the onset of estrus. Sows were housed in individual crates (6 × 1.8 ft) in an environmentally controlled gestation barn at the Kansas State University Swine Teaching and Research Center from breeding to mid-gestation. Sows were randomly allotted to one of two dietary treatments based on weight at breeding. All sows were fed 4.5 lb/d of a corn-soybean meal based gestation diet and received a 50 g top dress containing either 0 (control, n= 6) or 100 mg L-carnitine from d 1 to approximately d 57 of gestation. Day 1 was considered 12 hours after the first insemination. Sows were allowed *ad libitum* access to water.

At d 0, 28, and 57 of gestation, blood samples were collected 7 hours after feeding by puncture of the vena cava for determination of total and free carnitine and IGF-I. Blood samples were collected in both heparinized and non-treated tubes and were placed on ice until centrifuged (2,500 x *g* for 20 minutes at 39°F) or refrigerated (39°F) 48 hours before centrifugation, respectively. Plasma or sera was then separated and frozen (-4°F) until analysis. Microdetermination of carnitine concentrations in plasma and a two-sided immunoradiometric assay was used to determine IGF-I concentrations in sera.

Sows were anesthetized intravenously with sodium thiopental (8 mg/kg) before surgery, and the surgical plane of anesthesia was maintained by inhalation of halothane (2 to 5%). Additionally atropine sulfate (0.04 to 0.08 mg/kg) was administered intramuscular to decrease salivation. Sows underwent Caesarean section on d 54.5 to 59 of gestation. A mid-ventral incision was made and all blood flow to the uterus was ligated with ligatures on the ovarian stump and cervix. The uterus was removed and the abdominal layers were closed with absorbent sutures. Number and sex of fetuses were determined and recorded after the removal of the uterus from the sow. Fetal pigs were then removed and individually weighed and measured (crown to rump length). To calculate total litter weight, the sum of individual fetus weights was determined.

Statistical analyses for blood concentrations were performed with the MIXED procedure of SAS (SAS, 2000; SAS Inst. Inc., Cary, North Carolina). A split-plot analysis was conducted to account for repeated measurements that included the fixed effects of treatment and day of bleeding as the repeated measure. Satterthwaite adjustment was used for the degrees of freedom. Gestational growth data were also analyzed using the MIXED procedure of SAS. The model included treatment and feeding period with gestation day as a covariate. All treatment means were separated ($P<0.05$) using the Least Significance Difference (LSD) procedure when the respective F-tests were significant ($P<0.05$) unless otherwise stated.

Results and Discussion

No treatment by day interaction ($P>0.20$) was observed for circulating IGF-I or free carnitine (Figure 1). A day effect ($P<0.0001$) was detected for IGF-I (Figure 2) with circulating IGF-I higher ($P<0.05$) at d 0 of gestation than at d 28 or 55. Furthermore, as the number of gestation d increased from d 28 to 55, IGF-I concentrations numerically decreased. A treatment by day interaction ($P<0.05$) was observed for total carnitine (Figure 3). Sows fed L-carnitine had a higher ($P<0.05$) concentration of total carnitine at d 55 than did the control sows.

For the growth parameters, litter weights tended ($P=0.07$; Table 1) to be heavier in sows

fed L-carnitine compared to the controls. However, individual fetus weight did not differ ($P>0.05$) between the two treatments. Supplementing sows with L-carnitine resulted in larger ($P<0.05$) litters compared to litters from control fed sows. There was no affect ($P>0.05$) on fetus crown to rump length between treatments.

These results suggest that circulating IGF-I levels of gestating sows fed with or without L-carnitine are similar. Previous research has indicated that feeding sows L-carnitine during gestation had increased circulating IGF-I levels on both d 60 and 90 of gestation. These findings may explain why pigs farrowed from sows fed carnitine had heavier-muscled carcasses at slaughter compared to those from sows fed a control diet. The researchers suggested that the improvement observed in muscling of offspring from L-carnitine fed sows was a result of increased number of muscle fibers compared to the controls. Because IGF-I acts as a promoter of muscle growth it was suggested that the elevated IGF-I was having a proliferative affect on muscle cells allowing for improved carcass muscling. However the results of the current study suggest that the mode of action for L-carnitine improving muscling is not an endocrine effect by maternal IGF-I.

Feeding L-carnitine to gestating sows was beneficial for maintenance of fetal growth and development. The observed increase in total litter weight from sows fed L-carnitine suggests that L-carnitine affects growth by mid-gestation. Furthermore, individual fetus weight was unchanged between the two treatments, but the number of fetuses in the litters increased from 11 to 16 for control and carnitine fed sows, respectively. The carnitine was fed after ovulation and hence may increase the availability of nutrients to sustain more embryos and resulting in the observed increase in fetus number at mid-gestation. In addition to individual fetal weight, fetus crown to rump length was not affected by feeding L-carnitine, even though there was an increase in total litter weight. Therefore, the increased fetus number was not at the expense of fetal growth performance, a relationship that is normally inversely related.

Feeding L-carnitine resulted in greater variation of the relation of fetus number per litter to individual fetus weight compared to diets not containing carnitine (Figure 4). Even though there were more fetuses per litter from the sows supplemented L-carnitine, individual fetal weight was not negatively affected. In the litters from control fed sows, the range was smaller for both fetal weight and fetus number per litter. This suggests that the observed variation from feeding L-carnitine may be influenced by both the growth factor system and nutrient availability.

Due to the insemination of multiple sows on the same day, hysterectomies were completed on differing days of gestation. For both treatments, on average, litter weight increased as the number of gestation days increased (Figure 5). This suggests that mid-gestation is a time of rapid fetal growth and development. Interestingly, feeding L-carnitine resulted with heavier litters on each evaluated gestation d except d 59.

Feeding gestating sows L-carnitine increased number of piglets and total litter weight. Since, muscle development occurs before adipose tissue, the increase in litter weight indicates that fetal muscle mass may be increased in fetuses obtained from sows fed L-carnitine. In conclusion, producers can feed L-carnitine to gestating sows to take advantage of enhanced performance traits without negatively affecting fetal growth and development. More research should be conducted to further define the mechanisms that are affected by carnitine and that are responsible for the increased muscling in carcasses.

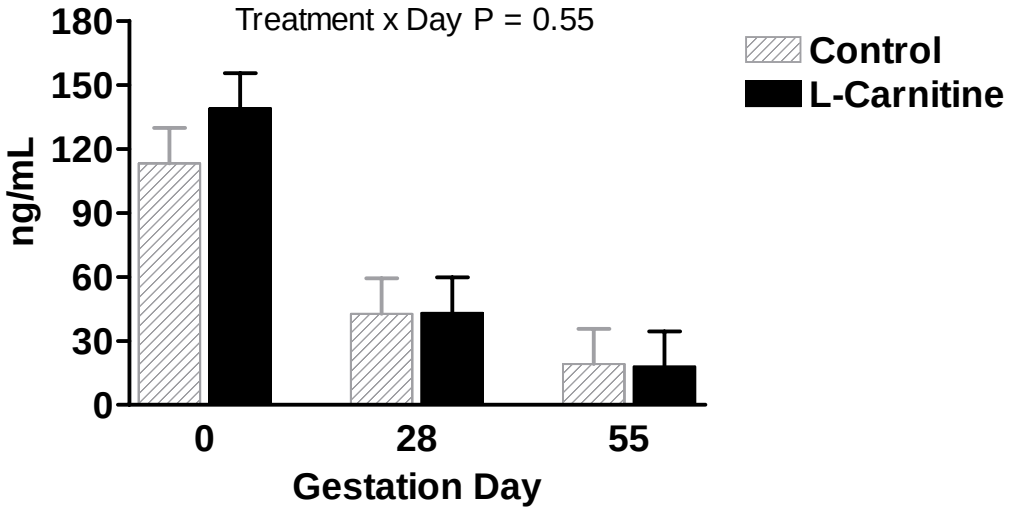

Figure 1. The influence of feeding sows L-carnitine on serum IGF-I concentrations.

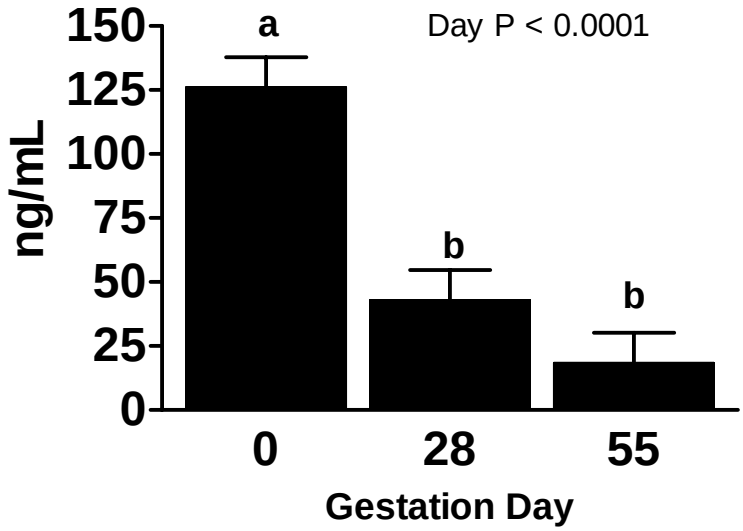

Figure 2. The influence of gestation day on maternal serum IGF-I concentrations.

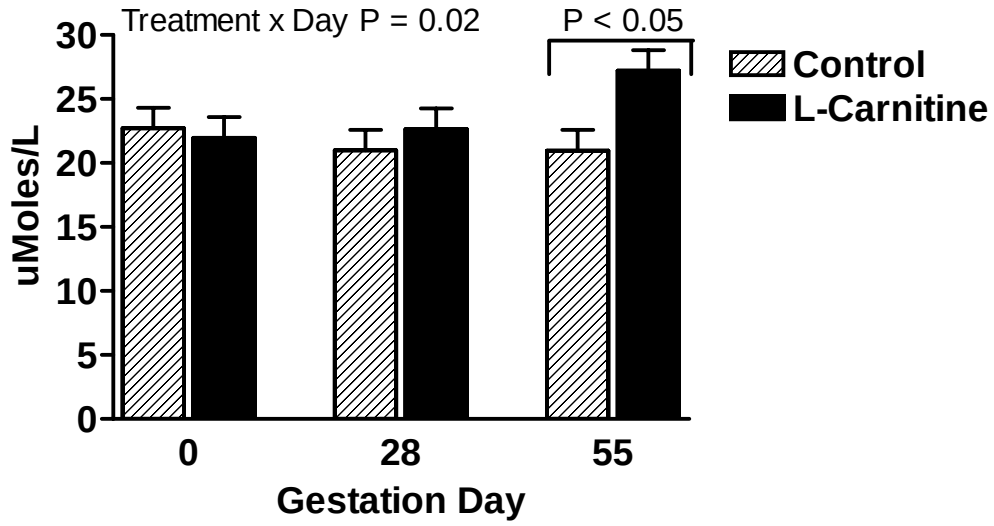

Figure 3. The influence of feeding sows L-carnitine on plasma total carnitine concentrations.

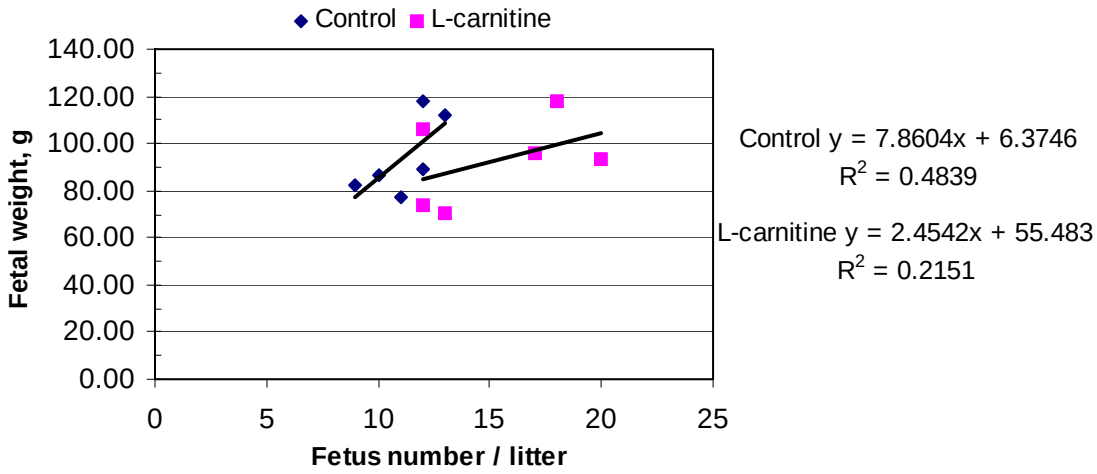

Figure 4. Relationship between the number of fetuses per sow and average fetal weight.

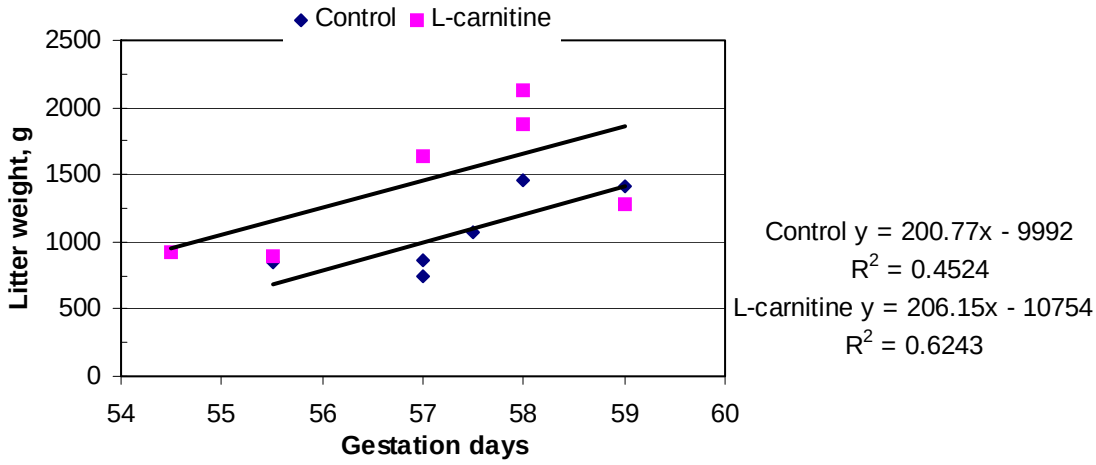

Figure 5. Relationship between number of gestation days on total litter weight.

Table 1. Effects of Feeding Gestating Sows L-carnitine on Fetal Growth Traits

	Control	L-carnitine	P-value
Initial sow weight, lbs	552.3	553.5	--
Number of fetuses	67	92	--
Gender of fetuses (75 female & 84 male)	--	--	--
Fetus number per litter	10.8[y]	15.5[x]	.019
Litter weight, g[a]	989.4[y]	1,449.6[x]	.068
Fetus weight, g	91.4	92.4	.880
Fetus crown to rump length, in	5.4	5.2	.085

[a]Litter weight was calculated by summing each individual fetus weight per litter.

[x,y]Means in the same row without a common superscript letter differ (P<0.05).

INFLUENCE OF CARNICHROME® ON ENERGY BALANCE OF GESTATING SOWS[1]

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Summary

Twelve multiparous sows were utilized in a randomized complete block design to determine the effects of feeding diets with or without Carnichrome® (50 ppm carnitine and 200 ppb chromium picolonate) on the components of heat production (HP) in early, mid and late gestation. All sows were fed dietary treatments for the 28 d lactation, and the subsequent weaning to estrus and gestation periods. The kinetics of HP and its partitioning (basal or resting HP, activity HP, and short term thermic effect of feeding (TEF_{st})) were determined during three stages of gestation, early (weeks 5 or 6), mid (weeks 9 or 10) and late (weeks 14 or 15) for each block. Feeding allowances were based on modeled calculations of energy and nutrient requirements to achieve a target sow maternal weight gain of 44 lb and remained constant throughout gestation. On d 111 of gestation sows were slaughtered and total uterus, individual fetal, placenta and empty uterus weights were recorded. Organic matter and energy digestibility for the Carnichrome® diet was greater ($P<0.05$) and fecal N excretion was lower ($P<0.05$), which resulted in the DE and ME content of the Carnichrome® diet being greater ($P<0.05$) compared to the control diet. Carnichrome® had no effect on total HP, energy retained as protein or lipid or maternal energy retention in early, mid or late gestation. Increased HP in late gestation was associated with increased uterine energy requirements. The ME intake on d 110 of gestation was 6.9 Mcal/d, but to prevent sows from mobilizing maternal tissues ME intake would need to be increased to 8.4 Mcal/d. This equates to a 21.5% increase in ME intake or an additional 1 lb/d of a corn soybean meal diet on d 110 of gestation than fed in the present experiment. Energy requirements for maintenance averaged 91 kcal/kg$BW^{0.75}$/d, and was greater in late compared with mid-gestation in the present experiment. On average 20% of ME intake was utilized for physical activity but ranged from 11.6 to 37.1%. Each 100 minutes of standing time/day represented an additional requirement of 0.38 lb/d of a standard corn soybean meal diet (1485 kcal/lb). The results of the present experiment indicate that improvements in reproductive performance found in previous experiments with carnichrome do not appear to be due to changes in heat production or improvements in energy retention. In con-

[1]Appreciation is expressed to Lonza, Inc., Fair Lawn, New Jersey, for partial financial support of this experiment.

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[3]Alberta Pig Company, 9189 Lochside Drive, North Saanich, British Columbia, Canada V8L 1N2.
[4]Food Animal Health and Management Center.
[5]Lonza, Inc., Fair Lawn, New Jersey.

clusion, Carnichrome® had no effect on the components of heat production and maternal weight gain during early-, mid- or late-gestation, but did improve energy and organic matter digestibility of the diet.

(Key Words: Sows, Carnichrome®, Heat Production, Gestation)

Introduction

Carnitine is a vitamin-like compound that is essential for the transport of long- and medium-chain fatty acids across the mitochondrial membrane for B-oxidation. Chromium is a trace mineral that is essential for activating specific enzymes and stabilizing proteins and nucleic acids. Both carnitine and chromium have been shown to improve reproductive performance of sows. In previous trials, we have observed the total number of pigs produced over two parities was greater when sows were fed diets with carnitine or chromium compared to sows fed control diets, with the greatest improvement observed from feeding a diet containing both carnitine and chromium. In other studies, sows gained more weight and backfat during gestation when fed diets containing carnitine. Sows fed chromium tended to gain more body weight during gestation compared to sows fed diets without chromium. These observations would suggest that the sows fed diets with carnitine or chromium retained more energy than the sows fed the diets without carnitine and chromium. The objective of the present study was to quantify the effect of the addition of carnitine and chromium (Carnichrome®) on heat production (HP) and its components and energy gain during early, mid- and late gestation of multiparous sows.

Procedures

A total of fifty-four Large White × Landrace sows were assigned to one of two dietary treatments post farrowing, control and Carnichrome® (50 ppm of L-carnitine and 200 ppb of chromium), based on parity and weight on entry to the farrowing house. All sows were fed dietary treatments for the 28-day lactation, the following weaning to estrus period, and to day 28 of the subsequent gestation. Once confirmed pregnant on day 28 of gestation, 12 sows (6 blocks with 2 sows per block) were selected for indirect calorimetry measurements. Sows were selected for indirect calorimetry measurements based on parity, weight entering the farrowing house, weight loss in lactation, and weaning to estrus interval. Energy balance was measured during three stages of gestation, early (weeks 5 or 6), mid (weeks 9 or 10) and late (weeks 14 or 15) for each block. Sows were housed for 7 days in the metabolism cage that was in a respiration chamber, where digestibility and energy balance measurements were taken simultaneously. Day 1 was used to allow the sow to adapt to the respiration chamber. Collection of urine and feces, and gas exchange measurements commenced on day 1. On the morning of day 8, the energy balance and digestibility measurements were terminated and sows were weighed. All sows on which indirect calorimetry measurements were taken were slaughtered at the end of pregnancy (day 111 on average) and total uterus, individual fetal, placenta, and empty uterus weights were recorded.

Two respiration chambers with a volume of 12 m^3 were available for measurement of gas exchange in individual sows. Metabolism cages were equipped with two infra-red (i.r.) beams located at the front and rear of the cages to detect standing or sitting activity of the sow. Interruption of an i.r. beam for at least 20 seconds was considered to represent a standing activity (i.e., sitting or standing). In addition, the metabolic cage was mounted on force sensors, which produced an electric signal assumed to be proportional to the physical activity of the animal. The temperature in the respiration chamber was maintained at 72°F.

A standard lactation diet, with 1.0% lysine, 0.80% calcium and 0.75% phosphorous was fed for the 28-d lactation. The experimental gestation diet was corn-soybean meal-based and formulated to contain 0.65% lysine, 0.80% calcium and 0.75% phosphorous (Table 1). The control diet had 0.05% of a corn-soy blend added, while the Carnichrome® diet had 0.05% of Carnichrome® 10% added to provide 50 ppm of L-carnitine and 200 ppb of chromium from chromium picolonate.

Table 1. Composition of the Experimental Diet

Item, %	Gestation Diet
Corn	80.07
Soybean meal (47% crude protein)	14.50
Dicalcium phosphate	2.58
Limestone	0.80
Soy oil	1.00
Salt	0.50
Corn-soy blend[a]	0.05
Vitamin and trace mineral	0.50
Calculated analysis	
Crude protein, %	13.6
Lysine, %	0.65
Calcium, %	0.90
Phosphorous, %	0.80
ME, kcal/lb	1499

[a]Corn-soybean meal blend (50:50) for the Carnichrome® treatment was replaced with Carnichrome® 10% blend which provided 50 ppm of L-carnitine and 200 ppb of chromium from chromium picolonate.

During the experiment, sows received their diet in one meal per day (9 a.m.) in pellet form. Feed allowances were based on modeled calculations of energy and nutrient requirements to achieve a target maternal weight gain during gestation of 44 lb. The gestational energy requirements were determined by calculating the daily energy requirement for maintenance (ME_M) multiplied by 115 days, plus energy for target weight gain, and energy for products of conceptus and uterine gain, and summing these to give the total gestation energy requirement. The calculations are:

ME_M (Mcal) = $0.107 \times BW^{0.75}$

Energy maternal gain (Mcal) = $(9.7 \times$ BW gain, kg + $54 \times$ P2 gain, mm$) \div 4.184$

Energy uterus gain (Mcal) = $((4.8 \times$ fetus BW gain, kg$) \div 0.5) \div 4.184$

BW is average body weight of the sow, which is calculated as weight at service plus one half targeted weight gain plus one half products of conceptus and uterine gain in gestation. Feeding level was kept constant over pregnancy.

Sows were weighed at the beginning, at the end of each collection period, and every two weeks between collections. Representative samples of feed, feces, and urine were collected during each measurement period. Feed and feces were analyzed for DM, ash, crude protein, crude fiber, diethyl ether and gross energy. Nitrogen in the urine was analyzed on fresh material, whereas the energy content was obtained after freeze-drying approximately 50 ml of urine in polyethylene bags.

Concentrations of O_2, CO_2 and CH_4 in the respiration chamber were measured continuously. Measurements of gas concentrations, signals of the force sensors and weights of trough and water-tank were averaged over 10 seconds and stored on a microcomputer for further analysis. Apparent digestibility coefficients of energy and the different chemical fractions were calculated. Daily heat production (HP) was calculated from gas exchanges. The retained energy (RE) corresponded to the difference in ME intake and HP. Energy retained as protein was calculated from the N balance, whereas retained energy as lipid cor-

responded to the difference between RE and energy retained as protein. Animals in the fed state were assumed to have a constant basal HP (kJ/d). Ingestion of a meal and associated short-term physiological events such as digestion and absorption cause a temporary increase of HP (TEF_{st}). The daily HP due to physical activity was calculated as the product of unitary HP (kJ/unit of force) and total force detected over a day.

The distribution of daily activity HP between eating (i.e. instability of the trough), standing (i.e., the difference between total duration of standing and the duration of eating) and lying periods was calculated as the production of activity HP (kJ/unit of force) and the total force measured during these periods. The RQ was calculated as the ratio CO_2 production:O_2 consumption. Model variables of HP were estimated for each day of measurement. In the subsequent statistical analysis, the mean of daily variables was used for each sow at each stage of pregnancy. There was a total of 36 experimental periods (12 sows and three stages of gestation).

The results were analyzed as a randomized complete block design with repeated measures over time using the MIXED procedure of SAS (SAS Inst., Carry, North Carolina). Sow was the experimental unit of analysis, with block included as a random effect. Heat production from day 93 to 111 of gestation was modeled as a function of day of gestation and adjusted for the sow effect to determine the increased daily heat production.

Results and Discussion

Both the control and Carnichrome® diets were analyzed for L-carnitine. The control and Carnichrome® diets contained 1.4 and 57.1 ppm of free L-carnitine, respectively. Average parity and sow weight at weaning, d 35, 70, 103 and 111 (slaughter) of gestation was not different between the control and Carnichrome® treatments (Table 2). Maternal weight gain in gestation averaged 47.5 lb, but no effect of Carnichrome® on maternal weight gain was observed. Metabolizable energy intake was targeted for sows to achieve a moderate weight gain throughout gestation, as it was hypothesized that the effects of Carnichrome® would be more prevalent at low energy intake levels. In mid-gestation when energy was retained in maternal tissues and in late gestation when sows mobilized lipid to meet the increased requirement for uterine growth, no effect of Carnichrome® was evident on any of the measured parameters. The prolificacy of the sows utilized in the present experiment was very high, with sows on average producing 16.5 total pigs with no difference between the two treatments. In the present experiment Carnichrome® had no effect on total number of fetuses produced, average fetal weight, total uterus, placenta or empty uterus weights. But it should be mentioned that the number of observations in the present experiment was very limited for such reproductive criteria.

Digestibility coefficient of organic matter and energy were greater for the Carnichrome® compared with control fed sows ($P<0.05$; Table 3). Dry matter digestibility coefficients increased with stage of gestation, while methane production decreased with stage of gestation. The energy content of the urine averaged 3.7%, and was greater in mid- compared with early- or late- gestation. The DE and ME value for the Carnichrome® diet was greater ($P<0.05$) than the control diet. The reduced ($P<0.05$) fecal N excretion for the Carnichrome® fed sows supports these data. Metabolizable energy value was greater ($P<0.05$) in early- and late- compared with mid-gestation. The digestibility of energy reported in the current experiment for a typical corn-soybean meal diet (92%) was greater than that predicted from DE values of corn and soybean meal proposed by the NRC (1998) or more recent values reported for growing pigs (88%). Digestibility coefficient for DM of the experimental diet was determined for growing

pigs to be 88% compared with 90.2% for sows. This is in agreement with the recent data from the University of Illinois that digestibility values for complete feeds were greater for sows compared with growing pigs and that diets should be assigned two energy values: one for growing pigs and one for sows.

Nitrogen losses in the feces were greater ($P < 0.02$) for the control compared with the Carnichrome® fed sows (Table 4). Losses of N in the urine were lower ($P < 0.01$) in early- and late-gestation compared with mid-gestation and N retention was greater ($P<0.01$) in early- and late-gestation compared with mid-gestation. The increased N retention in late-gestation was a result of the exponential fetal growth in late-gestation, which is mainly protein.

Heat production was greater ($P<0.01$) in late- compared with early- and mid-gestation and energy in gain was then lower ($P<0.01$) in late- compared with early- and mid-gestation (Table 4). The combination of the higher HP and higher protein (N) retention in late-gestation compared with early- and mid-gestation resulted in a decrease ($P<0.01$) in lipid deposition, with sows in late-gestation mobilizing lipid reserves. The lower ($P<0.01$) RQ in late- compared to mid-gestation confirms this result. As gestation progressed the composition of weight gain changed with lipid deposition decreasing and protein deposition increasing. Virtually all of the protein gains in late-gestation were deposited in the uterine tissues.

The efficiency of energy use for maternal gain averaged 67.9% for gestation in the present experiment, but was lower in late- compared with early and mid-gestation. The lower efficiency values reported in late-gestation are a result of the higher protein and lower lipid content of weight gain, as energy for protein deposition is utilized with a lower efficiency (60%) compared with lipid deposition (80%). Fetal and uterine energy retention increased ($P<0.01$) with stage of gestation especially between mid- and late-gestation. Increased HP and increased energy retained in the uterine tissues in late-gestation resulted in a decrease and negative maternal energy retention in late-gestation. Maintenance energy requirement as a percentage of ME intake averaged 76.4%, but was higher in late- compared with early- and mid-gestation.

Heat production in late-gestation increased 0.95 Kcal/kg $BW^{0.75}$ per d from d 93 to 111 (Figure 1). This is equivalent to an additional 23 g/d of a standard corn-soybean meal gestation diet (1,485 Kcal/lb ME) for a 500 lb sow. This is equivalent to an additional 23 g/d for each day from d 93 to 111 of a standard corn-soybean meal gestation diet (1,485 Kcal/lb ME) for a 500 lb sow. For example, on d 90 the additional feed requirement is 23 g/d which increases to 460 g/d (or lb/d) on d 110 of gestation. The increased HP can be explained mainly by the exponential fetal growth with energy retained in the uterus increasing from 0.52 to 0.79 Mcal/d and also the increased maintenance energy requirement associated with the additional weigh gain (Table 5). The large increase in HP in late-gestation in the present experiment can also be attributed to the high prolificacy of the sows used in the present experiment, with sows having on average 16.5 total pigs born. Maternal energy retention decreased from d 90 to 110 and sows were mobilizing maternal tissues on d 110 of gestation to meet the increased fetal energy requirements in late-gestation. The ME intake on d 110 of gestation was 6.9 Mcal/d, but to prevent sows from mobilizing maternal tissues ME intake would need to be increased to 8.4 Mcal/d (Table 5). This equates to a 21.5% increase in ME intake or an additional 1 lb/day of a standard corn-soybean meal diet on d 110 of gestation than fed in the present experiment.

The average time required to consume daily feed allowance was 20 minutes/d with an average rate of feed consumption of 100

g/minute (Table 6). Duration of total standing activity averaged 273 minutes/d and values ranged from 80 to 511 minutes/d. Activity HP (Mcal/d) while lying was greater ($P<0.01$) in late- compared with early- and mid-gestation. Irrespective of sow behavior, the energy cost of standing averaged 3.9 Kcal/minute or 0.07 Kcal/kg $BW^{0.75}$ per minute standing activity and was not affected by treatment or stage of gestation. Activity HP averaged 23.7% of total HP, but ranged from 14.2 to 41.5%, with large variation between individual sows. On average 22% of ME intake was used for physical activity. For sows standing for 150 minute/d or less AHP was similar to APH sows that are lying at approximately 9.6 Kcal/kg $BW^{0.75}$/d, but AHP was 3 times greater for sows that stood for approximately 500 minutes per d at 28.7 Kcal/kg $BW^{0.75}$/d (Figure 2). The higher duration of standing time in the present experiment compared to other experiments may be partly attributable to the low feeding level and low fiber content of the diet utilized in the present experiment. Physical activity can be quite variable and represent a major factor causing differences in maternal weight and backfat gains in gestation. For a 500 lb sow standing for an extra 100 minutes/d the additional feed requirement of corn-soybean diet (1485 kcal/lb) is 0.38 lb/d. A highly active sow that stood for 500 minutes/d requires an additional 1.9 lb/d to meet the energy requirement of the high activity.

In summary, organic matter and energy digestibility was greater and N excretion was lower for sows fed the Carnichrome® diet, which resulted in greater DE and ME values for the Carnichrome® compared to the control diet. When sows were fed Carnichrome® in gestation no effects were observed on HP or energy retention as protein or lipid in early-, mid- or late-gestation. Increased HP in late-gestation was associated with the increased uterine energy requirements and was determined as an additional 29 g/d of a standard corn-soybean meal diet (1,485 kcal/lb ME) from d 90 to 110 of gestation. ME intake on d 110 of gestation would need to have been increased 20% or 1 lb/day to prevent the sows from mobilizing maternal tissues. Energy requirement for maintenance averaged 76.4% of ME intake and was higher in late- compared with early- and mid-gestation in the present experiment. On average, 20% of ME intake was utilized for physical activity but there was large variation between individual sows in activity levels. For each additional 100 minutes/d standing an additional 0.38 lb/day of feed was required with highly active sows requiring as much as 1.9 lb/d more feed than low activity sows.

Table 2. Effect of Carnichrome® and Stage of Gestation on Sow whole Body and Uterine Growth

	Treatment			
	Control	Carnichrome®[a]	SED	P<
Number of sows	6	6		
Average parity	1.8	1.8		
Sow weight, lb				
Weaning	400.1	400.5	12.36	0.98
Day of gestation				
35	398.1	401.1	13.32	0.84
70	457.7	454.7	15.58	0.86
103	489.8	495.5	13.88	0.71
111 (slaughter)	499.4	505.9	15.16	0.69
Daily maternal weight gain (d 36-111), lb	0.61	0.67	0.09	0.54
Maternal weight gain, lb[b]	44.1	51.0	11.59	0.58
Weight, lb				
Total uterus	76.7	75.2	5.33	0.78
Fetuses	45.7	44.9	3.43	0.82
Placenta	9.5	9.5	1.00	0.99
Empty uterus	16.4	15.5	1.18	0.49
Total number of fetuses	17.3	15.7	1.74	0.34
Average fetal weight, lb[c]	2.67	2.91	0.25	0.37

[a]Provided 50 ppm of L-carnitine and 200 ppb of chromium from chromium picolonate.
[b]Slaughter weight – total fetal weight – placenta weight – weaning weight.
[c]At slaughter (d 111 on average of gestation).

Table 3. Effect of Carnichrome® and Stage of Gestation on Digestibility and Energy Values of the Dietary Treatments

	Treatment			Stage of gestation				P<		
Stage of gestation	Control	Carnichrome®[a]	SED	Early	Mid	Late	SED	Treat.	Stage	T×S
No. of observations	18	18		12	12	12				
Day of gestation	69	69		36	69	102				
Mean body weight, lb	446.5	450.8	12.69	398.2[b]	455.3[c]	492.5[d]	2.72	0.75	0.01	0.12
DM intake, lb/d[e]	3.90	3.90	0.06	3.87	3.91	3.92	0.02	0.99	0.23	0.79
Apparent digestibility, %										
DM	89.9	90.6	0.39	91.0[b]	89.5[c]	90.1[bc]	0.58	0.10	0.04	0.22
Organic matter	93.0	93.7	0.28	93.9	92.9	93.3	0.41	0.05	0.08	0.24
Crude protein	87.9	89.2	0.53	88.7	87.8	89.1	0.67	0.06	0.19	0.14
Energy	91.8	92.7	0.32	92.9	91.7	92.2	0.45	0.03	0.06	0.27
Energy of CH4 (% DE)	0.95	0.92	0.06	1.01[b]	0.97[b]	0.77[c]	0.06	0.65	0.04	0.11
Energy of urine (% DE)	3.72	3.69	0.10	3.61[b]	3.94[c]	3.57[b]	0.14	0.77	0.04	0.80
ME:DE (%)	95.5	95.4	0.17	95.3[b]	95.3[b]	95.9[c]	0.16	0.76	0.01	0.50
Energy values (Mcal/kg DM)										
DE	4.03	4.07	0.01	4.08	4.03	4.05	0.02	0.03	0.06	0.27
ME	3.84	3.88	0.01	3.89[b]	3.83[c]	3.87[b]	0.02	0.03	0.03	0.21

[a]Provided 50 ppm of L-carnitine and 200 ppb of chromium from chromium picolonate.
[bcd]Means with different superscripts differ ($P<0.05$).
[e]Dry matter content of the diet increased ($P<0.05$) with stage of gestation, 88.1, 88.5 and 88.9%.

Table 4. Effect of Treatment and Stage of Gestation on Nitrogen and Energy Balance of Sows

	Treatment			Stage of Gestation				P<		
Item	Control	Carnichrome®[a]	SED	Early	Mid	Late	SED	Treat.	Stage	T×S
Number of observations	18	18		12	12	12				
Day of gestation	69	69		36	69	102				
Nitrogen balance, g/d										
Intake	44.4	44.5	0.72	44.2	44.5	44.7	0.22	0.93	0.12	0.86
Losses										
Feces	5.3	4.8	0.20	5.0	5.4	4.9	0.29	0.02	0.21	0.14
Urine	21.2	21.5	0.84	20.5[b]	23.7[c]	19.9[b]	0.83	0.72	0.01	0.52
Evaporation	1.4	1.4	0.20	1.3	1.4	1.4	0.31	0.87	0.95	0.87
Retention	16.3	16.4	0.89	17.0[b]	13.9[c]	18.3[b]	0.94	0.89	0.01	0.31
Energy balance, Mcal/d										
ME intake[e]	6.79	6.87	0.11	6.84[bc]	6.78[b]	6.89[c]	0.05	0.52	0.03	0.10
Heat production	5.73	5.75	0.21	5.39[b]	5.52[b]	6.31[c]	0.11	0.93	0.01	0.70
Energy gain	1.06	1.13	0.16	1.44[b]	1.26[b]	0.58[c]	0.12	0.69	0.01	0.94
Energy gain as										
Protein	0.58	0.59	0.03	0.61[b]	0.50[c]	0.65[b]	0.03	0.89	0.01	0.31
Lipid	0.48	0.54	0.14	0.84[b]	0.76[b]	-0.08[c]	0.13	0.66	0.01	0.93
Energy gain in										
Fetal tissues	0.26	0.25	0.03	0.01[b]	0.18[c]	0.57[d]	0.03	0.71	0.01	0.90
Uterine tissues	0.35	0.34	0.03	0.10[b]	0.30[c]	0.63[d]	0.03	0.69	0.01	0.91
Maternal tissues	0.75	0.86	0.18	1.36[b]	1.01[c]	-0.03[d]	0.14	0.57	0.01	0.85
Maintenance % ME intake	76.8	75.9	2.97	70.0[b]	73.8[b]	85.3[c]	2.06	0.79	0.01	0.88
Respiratory quotient	1.00	1.00	0.01	1.02[b]	1.01[b]	0.97[c]	0.01	0.62	0.01	0.28

[a]Provided 50 ppm of L-carnitine and 200 ppb of chromium from chromium picolonate.
[bcd]Means with different superscripts differ ($P<0.05$).
[e]Dry matter content of the diet increased ($P<0.01$) with stage of gestation, 88.1, 88.5 and 88.9%.

Table 5. Effect of Day of Gestation on Heat Production, Uterine and Maternal Energy Retention

	Day of Gestation		
Item	90	110	110[a]
Body weight, lb	474	507	507
Mcal/d			
ME intake	6.90	6.90	8.37[b]
HP	5.65	7.20	7.58
Uterine energy retention	0.52	0.79	0.79
Maternal energy retention	0.72	-1.09	0

[a]Increased energy intake on d 110 of gestation to result in 0 maternal energy retention.
[b]ME intake for 0 energy retention, using an efficiency of energy retention for gain of 74%.

Table 6. Effect of Treatment and Stage of Gestation on Standing and Physical Activity of Sows

	Treatment			Stage of Gestation				P<		
Item	Control	Carnichrome®[a]	SED	Early	Mid	Late	SED	Treat.	Stage	T×S
No. of observations	18	18		12	12	12				
Day of gestation	69	69		36	69	102				
Behavior, min/d										
Eating	24	19	2.52	22	22	21	0.83	0.10	0.48	0.77
Standing not eating	240	265	69.80	271	251	235	24.03	0.73	0.49	0.45
Total standing	263	284	71.49	290	273	257	19.49	0.79	0.28	0.48
Percent of day spent standing	18.2	19.7	4.83	20.3	18.9	17.7	1.71	0.77	0.49	0.47
Activity HP, Mcal/d										
Total	1.41	1.58	0.28	1.35	1.48	1.65	0.14	0.57	0.20	0.96
Standing and/or eating	0.11	0.09	0.02	0.09	0.10	0.11	0.01	0.55	0.43	0.48
Standing and/or not eating	0.77	0.95	0.19	0.89	0.85	0.84	0.09	0.39	0.89	0.44
While lying	0.54	0.54	0.16	0.37[b]	0.53[b]	0.71[c]	0.10	0.99	0.04	0.78
Standing HP, kJ/min	15.9	16.7	1.64	15.4	16.9	16.4	1.20	0.99	0.66	0.21
Standing HP, kJ/kgBW$^{0.75}$ per min	0.29	0.31	0.03	0.31	0.30	0.28	0.02	0.99	0.73	0.26
Rate feed consum., g/min.	90	111	11.2	99	99	103	3.90	0.10	0.52	0.52

[a]Provided 50 ppm of L-carnitine and 200 ppb of chromium from chromium picolonate.
[bc]Means with different superscript letters differ (P<0.05).

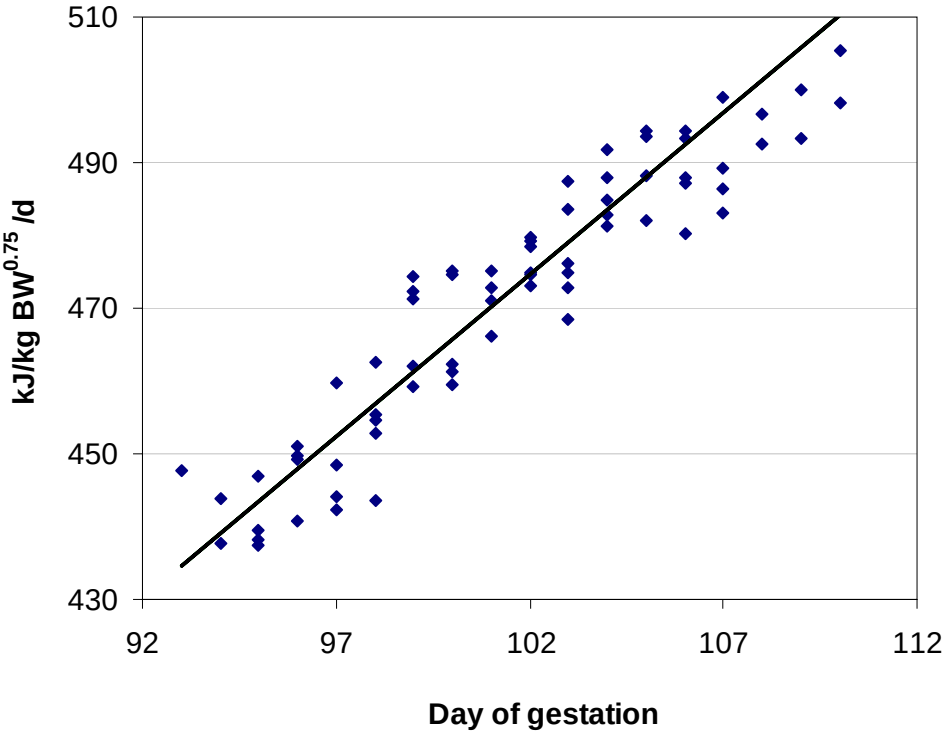

Figure 1. The relationship between day of gestation and heat production (HP). HP (kJ/kg $BW^{0.75}$/d) = 4.5(day of gestation) + 20; adjusted for the sow effect. R^2 = 0.85.

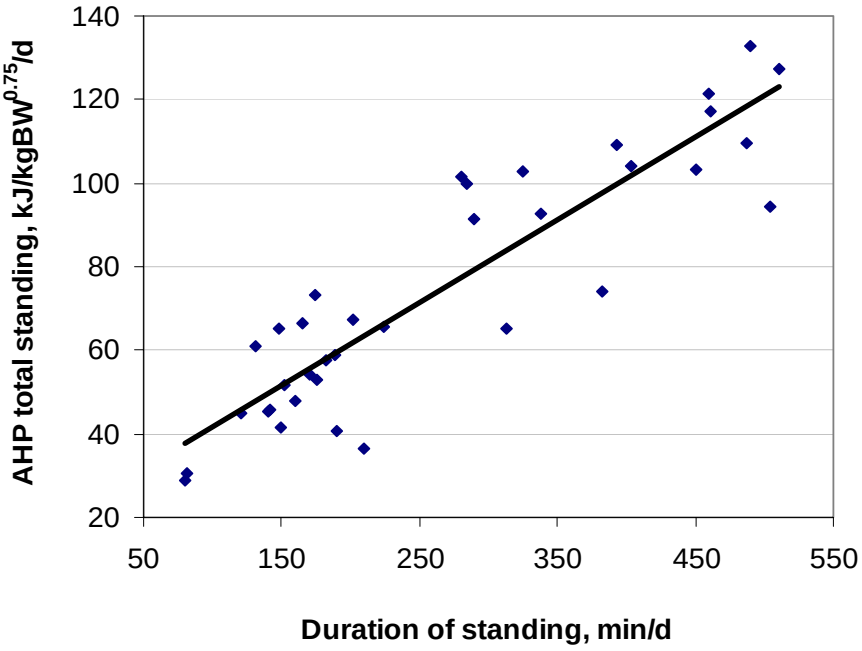

Figure 2. The relationship between duration of standing (min/d) and AHP during total standing time (kJ/kg$BW^{0.75}$/d). AHP (kJ/kg$BW^{0.75}$/d) = 0.2(duration of standing, minutes/d) + 22; R^2=0.81.

COMPARISON OF THREE METHODS OF FEEDING SOWS IN GESTATION AND THE SUBSEQUENT EFFECTS ON LACTATION PERFORMANCE

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Summary

A total of 684 sows from breeding groups over six weeks were used to compare three methods of feeding during gestation and to assess the subsequent effects on lactation performance. Control gilts and sows were fed according to body condition based on a scale of 1 to 5, (1=thin, 5=fat). Sows were visually assessed for body condition at breeding and were assigned a daily feed allowance to achieve a body condition score of 3 at farrowing. Sow body condition was evaluated every two weeks throughout gestation, and feed allowance was adjusted as required.

Treatment two used feeding levels based on backfat thickness (measured between d 0 and 5 after breeding) and weight at weaning for sows or weight at service for gilts. Feed allowance was calculated to achieve a target backfat of 19 mm at farrowing. Sow feeding level remained constant from d 0 to 101 of gestation. Feed allowances were based on modeled calculations of energy and nutrient requirements to achieve target sow maternal weight and backfat gain.

Treatment three was identical to treatment two except that feeding pattern was altered for thin sows and gilts (<15 mm at service) in an attempt to reach 19 mm by d 36 of gestation. Sows were weighed at the previous weaning and gilts at-service and again between d 112 and 114 of gestation. Backfat was measured between d 0 and 5 and again between d 108 and 113 of gestation.

Sows on treatments two and three achieved backfat of 19 and 19.1 mm at farrowing, respectively, while control sows numerically tended to have greater backfat at farrowing (20 mm). On average, sows targeted to gain large amounts (6 to 9 mm) of backfat in gestation failed to achieve target gains regardless of feeding method. Feeding sows in gestation based on backfat (treatments two and three) resulted in a higher proportion of sows in the target backfat range of 17 to 21 mm at farrowing and a lower percentage of fat sows (>21 mm) but no difference in the percentage of thin sows (<17 mm) compared to the standard method of feeding based on body condition.

Gestation feeding method had no effect on performance during lactation. Feed intake in lactation was lower for high backfat sows (>21 mm) at farrowing compared to sows with <21 mm. The high proportion of sows in the

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optimum backfat category demonstrates that feeding based on backfat and body weight has potential for facilitating more precise gestation feeding.

(Key Words: Sows, Backfat, Body Condition Score)

Introduction

Maintaining adequate body tissue reserves throughout a sow's lifetime is thought to be important to maximize herd productivity. Concern has increased regarding the fat and muscle mass with which the young gilt begins her reproductive life. However, research investigating the relationship between gilt body composition at breeding and subsequent sow longevity has produced conflicting results. A large study using 1,072 large white sows, reported that backfat depth at mating was positively related to lifetime productivity. In contrast, there are ample experimental data, using various genetic lines and in different production systems, indicating that body condition of gilts at first successful breeding has no relationship with culling rate over three or four parities.

One common method of feeding gestating gilts and sows on commercial farms is to provide them with an amount of feed throughout gestation to achieve a visual body condition score (BCS) of 3 at farrowing on a scale of 1 to 5 (1 very thin to 5 very fat). Daily feed allowances are based on body condition using some arbitrary scale. Body condition score and backfat have been shown to be poorly comparable. In spite of the considerable research, there is a lack of consensus as to the best strategy for feeding pregnant sows.

Modern sows are younger and leaner at the time of mating, have poorer appetites, are more fertile, and produce more milk than sows of 5 to 10 years ago. The challenge is to develop feeding programs that support this new level of performance. Thus, our objectives were to compare three methods of feeding sows in gestation over one parity and to monitor subsequent lactation performance.

Procedures

The experiment was conducted on a 2,500 sow farrow-to-wean operation in Missouri. A total of 684 sows (Camborough 22; PIC USA, Franklin, Kentucky) sows were randomly allotted to treatments within the first 5 days after service. During gestation, sows were fed a corn-soybean meal based diet formulated to contain 0.6% lysine, 0.98% calcium and 0.67% P (Table 1).

There were three experimental treatments. Control gilts and sows were fed following the farm's normal procedure of feeding sows based on body condition score (Control; Table 2). A body condition score was visually determined and sows were assigned condition scores ranging from 1 to 5, (1 being very thin (emaciated), 3 in condition, and 5 very fat). Treatment two used feeding levels based on backfat thickness, measured between d 0 and 5 after breeding, and initial weight for sows and weight at service for gilts. The assigned feeding level remained constant from d 0 to 101 of gestation (Table 3). Backfat was measured at the P2 position (last rib, 2.5 inches from the center line of the back) on both sides of the backbone using a Lean-Meater (Renco Corporation, Minneapolis, Minnesota). Values from the two measurements were averaged to obtain a single backfat measurement. Feed allowance was calculated to achieve a target backfat of 19 mm at farrowing. Feeding levels for sows assigned to treatment three were based on backfat thickness measured between d 0 and 5 after breeding and initial weight for sows and weight at service for gilts. But thin sows and gilts with less than 15 mm of backfat at breeding had their feed level adjusted again on d 36 of gestation (Tables 4 and 5). The objective of this strategy was to target 19 mm of backfat for thin sows and gilts (P2 <15 mm) on d 36 of gestation. For the last 2 weeks of gestation (d 102 to 115), all gilts and sows on

all three feeding methods received 2 lb of feed per d in addition to d 100 feed level.

Feed allowances for treatments two and three were based on modeled calculations of energy and nutrient requirements to achieve target sow maternal weight and backfat gain. The gestational energy requirements were determined by calculating the daily energy requirement for maintenance (ME_M) multiplied by 115 days, plus energy for maternal gain, and energy for products of conceptus and uterine gain, and summing these to give the total gestation energy requirement. The calculations used were:

ME_M (MJ) = 0.45 × $BW^{0.75}$, kg
Energy maternal gain (MJ) = 9.7 × BW gain, kg + 54 × P2 gain, mm
Energy uterus gain (MJ) = (4.8 × fetus BW gain, kg) ÷ 0.5

Where BW is average body weight of the sow, which is calculated as weight at service plus one half targeted maternal weight gain plus one half products of conceptus and uterine gain in gestation. P2 gain is the targeted increase in required backfat to achieve a target backfat of 19 mm at farrowing.

The gestation feed box (Chore-Time Equipment, Milford, Indiana) could feed up to 10 lb in one delivery, and feed was delivered once daily at 7 a.m. The feed box setting for all sows was recorded to determine total gestation feed consumption. Prior to the start of the experiment, a representative sample of feed boxes was tested over a variety of different feed allowances (2 through 10 lb of feed). To provide 4 lb of feed the feed box was set at 3.7 lb (Target feed level, lb = 0.886 × actual feed level + 0.168). This regression equation was then used to adjust the feed box settings to provide the correct amount of feed.

Sows and gilts were weighed again between d 112 and 114 of gestation when entering the farrowing barn. Backfat measurements were also taken between d 108 and 113 of gestation. Protein and fat mass was estimated using published prediction equations (Dourmad et al., 1997). Three temperature recorders (Hobo, Animal Environment Specialists Inc, Marysville, Ohio) were placed in the gestation barn to monitor barn temperatures throughout gestation. For the first 35 days of gestation, all sows were housed in the breeding barn in individual gestation sow stalls (2 × 7 ft). After pregnancy confirmation, they were moved to the gestation barn where they were also housed in individual gestation sow stalls for the remainder of gestation. Both the breeding and gestation barns were double-curtain sided, fully-slatted barns.

Sows were fed ad libitum using the Quincy Development and Manufacturing ad libitum feeder (Hog Slat, PO Box 300, Newton Grove, NC 28366), which had a hopper with a capacity of up to 11 lb and was filled twice daily at 9 a.m. and 2:30 p.m. Sows were fed a corn-soybean meal, added fat diet formulated to contain 1.0% lysine, 0.91% ca and 0.71% P (Table 2). Feed intake was determined by recording the number of containers containing 4 lb of feed that was used to fill the sow feeders. Any feed removed from the feeder was recorded. Total numbers of pigs born, born alive, born dead, mummified, and fostered were recorded. At weaning, the number of pigs weaned and date of weaning were recorded on the feed intake card. Sows were weighed and backfat was measured at weaning. The date of weaning and estrus was recorded and used to calculate the percent of sows returning to estrus by 7 days post weaning.

Data were analyzed as a completely randomized design using the MIXED procedure of SAS. Sow was the experimental unit of analysis. Treatment (n=3) was the main effect tested. A chi square statistic was used to determine if there was evidence of significant differences in the number of sows removed from the experiment and the percent of sows

returning to estrus in 7 days post weaning across treatments.

Results and Discussion

Gestation barn temperatures averaged 67.6 ± 4.8°F for the duration of the trial. Between service (initiation of the experiment) and entry to the farrowing house, 18.9, 20, and 16 % of sows started on the experiment were removed on the control and treatments two and three. From farrowing to weaning 3.2, 2.8, and 2.6 % of sows were removed from the experiment on control and treatments two and three.

Average daily feed intake for gestation was greater ($P<0.05$) for control sows at 5.7 lb, compared to sows on treatments two and three at 5.1 lb. Sow initial and farrowing weight did not differ ($P>0.10$) among the three treatment groups (Table 6). From the start of the experiment to entering the farrowing house, control sows gained more ($P<0.01$) weight than sows on treatments two and three. Sows on treatments two and three had an average backfat of 19 and 19.1 mm at farrowing, respectively. This was close to the target backfat of 19 mm at farrowing. However, control sows tended to have greater ($P=0.07$) backfat at farrowing (20 mm) than sows on treatments two and three. Also, control sows had greater ($P<0.01$) backfat gain during gestation than those on treatment two, and tended to have greater backfat gain than those on treatment three ($P<0.06$). The standard deviation of backfat from the start of the experiment to farrowing increased for the control and treatment two sows from 3.6 and 3.3 mm to 3.9 and 3.6 mm respectively, while the standard deviation of backfat for treatment three remained unchanged at 3.6 mm. Predicted maternal weight gain, using the NRC (1998) model, was similar to the actual maternal weight gains (± 1.8). Using estimated protein and fat mass gain from initiation of the experiment to entering the farrowing house, control sows gained more ($P<0.03$) protein and fat mass than sows on treatments two and three.

On average, sows on treatments two and three that were predicted to gain no backfat, actually gained 1.9 mm of backfat (Table 7). Sows predicted to gain 3 mm of backfat gained 2.9 mm. Sows predicted to gain 6 and 9 mm of backfat gained only 3.5 and 4.7 mm, respectively. Control sows that needed to gain 6 and 9 mm of backfat also failed to meet these targets. Estimated maternal weight gains were in excess of predicted weight gains for the 28 and 44 lb predicted maternal weight gain groups on feeding methods two and three. However, sows predicted to gain 60 and 77 lb of maternal weight failed to achieve predicted gains.

From service to farrowing, the percentage of sows with <17 mm of backfat decreased and the percentage of sows within the backfat range of 17 to 21 mm increased for all three feeding methods (Table 8). The largest increase in the percentage of sows between 17 to 21 mm was achieved with treatment three at 19.6%; for treatment two the increase was 17.0%; while for control sows the percentage was increased by 7.6%. From service to farrowing, the percentage of fat sows (>21 mm) increased for all three treatments. There were 28.3% more control sows in this category at farrowing compared with service. In contrast, for treatments two and three, the increase was 14.3 and 19.6%, respectively. Feeding sows in gestation based on backfat (treatments two and three) resulted in a higher percentage of sows (53%) at farrowing in the target backfat range of 17 to 21 mm, and fewer (22 to 27.3%) very fat (>21 mm) sows at farrowing compared to feeding based on body condition score (control; Figure 1).

Sows with <17 mm of backfat at farrowing represented 21.6, 23.3 and 21.7% of control sows and sows on treatments two and three, respectively (Table 9). It is desirable to have sows ≥17 mm at farrowing to allow sows to lose 3 to 4 mm of backfat and not fall below 13 mm of backfat at their subsequent service. The percentage of low-backfat sows was

evenly distributed across parities for the three treatments. For estimated maternal weight and backfat gains, thin sows that had less than 17 mm of backfat at farrowing failed to achieve predicted maternal weight and backfat gains, regardless of treatment.

Average daily feed intake in lactation was not affected by gestation feeding method (Table 10). Performance in lactation and from weaning-to-estrus was not affected ($P>0.10$) by gestation feeding method. Backfat at farrowing was higher and at weaning tended to be higher ($P = 0.07$) for the control sows compared with sows on treatments two and three. Sows on treatment three had greater ($P<0.05$) subsequent total born and born alive compared to sows on control and treatment two.

Feed intake in lactation was decreased for sows with >21 mm of backfat at farrowing. Sows in the <17 mm and 17-21 mm backfat categories at farrowing had greater ($P<0.05$) feed intake in lactation compared to sows with >21 mm of backfat at farrowing (Table 11). As parity increased, feed intake in lactation increased ($P<0.05$), while backfat loss decreased. Estimated fat mass loss was greater for parity 1 compared to parity 2 sows ($P<0.05$). There was a decrease ($P<0.05$) in total born and born alive between parity 1 and 2 sows. The number of mummies was higher ($P<0.05$) for parity 1 sows compared to parity 2 and 3+ sows. There was no difference in the subsequent total born, born alive, born dead, and mummies between the control and treatments two and three.

Sows that were thin (<17 mm) at farrowing had lower weight at farrowing and weaning ($P<0.01$; Table 11) relative to sows in the target backfat range (17-21 mm) and fat sows (>21 mm) at farrowing. Also, thin sows tended to lose less weight ($P<0.07$) in lactation compared to sows in the target backfat range and fat sows. As expected, sow backfat loss in lactation was lower ($P<0.01$) for the thin sows compared to sows in the target backfat range and fat sows at farrowing. There was no difference in total number of pigs born, born alive, born dead, mummified, fostered and weaned between the thin and other sows. Fat sows (>21 mm) at farrowing had significantly lower subsequent total born and born alive than sows in the target backfat range, and tended ($P=0.09$) to have lower subsequent total born and born alive than thin sows.

Feeding sows in gestation based on backfat (treatments two and three) compared to the standard system of feeding based on body condition (control) resulted in a higher proportion of sows in the target backfat range of 17 to 21 mm at farrowing with a lower percentage of fat sows (>21 mm), but no difference in the percentage of thin sows (<17 mm). It is desirable to have sows ≥17 mm at farrowing to allow sows to lose 3 to 4 mm of backfat and not fall below 13 mm of backfat at their subsequent service. Data from several studies have shown that low backfat levels at weaning (<14 mm) compromise subsequent performance. Gestation feeding method had no effect on sow performance in lactation in our experiment. Sows with high backfat at farrowing (>21 mm) had lower feed intake in lactation. This agrees with previous research where a negative relationship has been established between backfat depth at farrowing and lactation feed intake.

There are critical factors in any gestation-feeding program that can lead to inaccuracies, although we believe using a feeding method based on backfat measurements is a viable alternative. A high proportion of sows targeted to gain 6 and 9 mm of backfat on all three treatments failed to gain predicted backfat. Thin sows (sows targeted to gain 6 and 9 mm) tend to be more active (standing-up more often) thereby expending more energy. Thin sows that failed to gain target backfat in gestation are a major concern. We believe that backfat may need to be measured again during

mid-gestation in these thin sows and their feed allowance adjusted accordingly. It is also possible that the amount of daily feed intake required to achieve large gains in backfat may be greater than the sow's normal appetite. A strategy may need to be developed for sows needing to gain 6 to 9 mm to allow them to achieve the large backfat gain over two parities instead of one. Also some of these sows may never gain enough backfat, no matter how much feed they receive, and possibly will continue to lose backfat over successive parities until they are removed from the herd. Irrespective of kinetics of energy (feed) supply, high feed level in early gestation (treatment three sows <15 mm at service) or a constant feeding level (treatment two) throughout gestation, there was no effect on performance in gestation or lactation.

In conclusion feeding gestating sows based on modeled nutrient requirements from weight at weaning and backfat at service appears to be a viable alternative to the commonly used visual body scoring systems. Feeding based on backfat and weight resulted in a lower proportion of sows too fat at farrowing and a similar percentage of thin sows compared to the visual body scoring system. Gestation feeding method had no effect on performance in lactation. Thin sows (targeted to gain 6 and 9 mm) failed to gain their targeted backfat in gestation regardless of feeding method.

Table 1. Composition of the Gestation and Lactation Diets (As-fed Basis)

Ingredient, %	Gestation	Lactation
Corn	83.56	68.19
Soybean meal (48% crude protein)	12.50	23.80
Choice white grease	-	3.45
Di-calcium phosphorous	1.70	1.68
Limestone	1.47	1.19
Salt	0.50	0.50
Dynamate	-	0.75
Lysine	-	0.13
Methionine	-	0.06
Mineral and vitamins	0.27	0.25
Nutrient composition		
Lysine, %	0.60	1.00
Calcium, %	0.98	0.91
Phosphorous, %	0.67	0.71
ME, kcal/lb	1,487	1,561

Table 2. Feed Level (lb/d) for Sows and Gilts on the Control Treatment Based on Body Condition Scoring[a]

Day of gestation	Condition score	Sows	Gilts
1-4		4.5	4.0
5-35	1	8-10.0	7.5-9.5
	2	6.0	5.5
	3	5.0	4.5
	4	4.5	4.0
	5	4.5	4.0
36-101	≥3	4.5	4.0
	<3	5.0	4.5

[a]From d 102 to 115 all sows received 2 lb/d in addition to d 100 feed level.

Table 3. Feeding Level (lb/d) for Sows on Treatment Two from Day 0 to 101[a]

	P2 at Breeding, mm			
Weight, lb	<12	12 to 14.9	15 to 17.9	≥ 18
<325	4.8	4.3	3.8	3.3
325-400	5.2	4.8	4.3	3.8
400-475	5.7	5.2	4.7	4.2
> 475	6.2	5.7	5.2	4.7

[a]From d 102 to 115 all sows received 2.0 lb/d in addition to d 100 feed level.

Table 4. Feeding Level (lb/d) for Sows on Treatment Three with < 12 mm or 12 to 14.9 mm of Backfat[a]

	Day of Gestation		
	0 to 35		36 to 101
Weight, lb	< 12 mm	12 to 14.9 mm	
<325	6.4	4.8	4.0
325-400	8.0	6.4	4.0
400-475	7.2	5.6	5.0
> 475	8.8	7.2	5.0

[a]From d 102 to 115 all sows received 2.0 lb/d in addition to d 100 feed level.

Table 5. Feeding Level (lb/d) for Sows on Treatment Three with 15 to 17.9 mm or ≥ 18 mm of Backfat[a]

	Day of Gestation	
	0 to 101	0 to 101
Weight, lb	15 to 17.9 mm	≥18 mm
<325	3.8	3.3
325-400	4.3	3.8
400-475	4.7	4.2
> 475	5.2	4.7

[a]From d 102 to 115 all sows received 2.0 lb/d in addition to d 100 feed level.

Table 6. Effect of Feeding Method on Weight, Backfat, Estimated Protein and Fat Mass Gain in Gestation

		Treatment			
Item	Control	Two	Three	SE	P<
Number of sows	185	180	194	-	-
Average parity	2.9	3.3	3.0	0.30	0.51
Daily feed intake, lb	5.7[a]	5.1[b]	5.1[b]	0.07	0.01
Sow weight, lb					
Initial	469.7	482.3	477.7	11.87	0.59
Farrowing	579.3	576.9	571.2	10.80	0.75
Weight gain	109.1[a]	93.4[b]	92.8[b]	4.54	0.01
Estimated post-farrowing[c]	532.8	530.8	525.5	10.78	0.79
Estimated maternal gain lb[d]	62.6[a]	47.3[b]	47.1[b]	4.54	0.01
Sow backfat, mm					
Service	16.3	16.4	16.1	0.37	0.71
Farrowing	20.0	19.0	19.1	0.40	0.07
Gain	3.6[a]	2.6[b]	2.9[ab]	0.26	0.01
Predicted gains					
Maternal weight gain, lb[e]	64.0[a]	46.8[b]	48.9[b]	2.71	0.01
Total weight gain, lb[f]	109.3	93.6	93.0	-	-
Backfat gain, mm[e]	6.4[a]	3.3[b]	3.7[b]	0.48	0.01
Estimated protein mass, lb[g]					
Initial	76.6	78.8	78.3	1.99	0.55
Farrowing	85.2	85.5	84.5	1.89	0.88
Gain	8.5[a]	6.5[b]	6.2[b]	0.76	0.03
Estimated fat mass, lb[h]					
Initial	93.6	96.5	94.6	3.20	0.67
Farrowing	118.2	115.0	114.0	2.81	0.34
Gain	24.3[a]	18.0[b]	19.0[b]	1.48	0.01

[ab]Means with different superscripts on the same row differ (P<0.05).
[c]Farrowing weight – (Total born × 4.1 lb).
[d]Post-farrowing weight – Initial weight.
[e]Predicted based on actual feeding levels provided in gestation (NRC, 1998).
[f]Maternal weight gain plus uterine weight gain (Total born × 4.1 lb).
[g]Prediction equation from Dourmad et al. (1997), 2.28 + 0.178 × (liveweight, kg) – 0.333 × (backfat, mm).
[h]Prediction equation from Dourmad et al. (1997), -26.40 + 0.221 × (liveweight, kg) + 1.331 × (backfat, mm).

Table 7. Target Versus Actual Backfat, Estimated Maternal Weight Gain, Estimated Protein and Fat Mass Gains for Treatments Two and Three

	Target P2 gain, mm ± SD			
Item	0	3	6	9
Number of sows				
Treatment two	51	68	51	10
Treatment three	49	74	47	24
Actual P2 gain, mm				
Treatment two	1.7 ± 2.9	2.9 ± 2.6	2.9 ± 2.4	4.9 ± 2.9
Treatment three	2.0 ± 2.1	2.8 ± 2.4	4.0 ± 2.7	4.5 ± 2.8
	Target maternal weight gain, lb ± SD			
	28	44	60	77
Estimated maternal weight gain, lb				
Treatment two	33.5 ± 48.5	59.7 ± 34.4	43.9 ± 44.1	65.9 ± 50.5
Treatment three	31.7 ± 38.6	52.9 ± 45.4	52.0 ± 51.4	63.7 ± 38.1
Estimated protein mass gain, lb				
Treatment two	5.5 ± 8.6	10.4 ± 6.2	7.5 ± 7.9	11.5 ± 9.0
Treatment three	5.3 ± 6.8	9.0 ± 8.2	9.0 ± 9.0	11.0 ± 6.8
Estimated fat mass gain, lb				
Treatment two	12.1 ± 15.4	21.6 ± 12.8	17.9 ± 13.7	28.7 ± 15.4
Treatment three	12.6 ± 11.7	19.6 ± 14.8	23.1 ± 17.0	27.1 ± 14.3

Table 8. Percentage of Sows at Service and Farrowing in Each Backfat Range[a]

	Service			Farrowing		
Treatment	Control	Two	Three	Control	Two	Three
Backfat, mm						
<17	58.2	56.6	59.3	22.3	24.7	20.1
17-21	32.6	36.3	33.0	40.2	53.3	52.6
>21	9.2	7.7	7.7	37.5	22.0	27.3

[a]Values represent 185 control sows, 180 sows on treatment two, and 194 sows on treatment three.

Table 9. Low Backfat Sows (<17 mm) at Farrowing by Parity, Weight and Backfat

		Treatment			
Item	Control	Two	Three	SE	P<
Number of sows	40	42	42	-	-
Percent of sows	21.6	23.3	21.7	-	-
Average parity	3.1	3.1	3.0	0.65	0.99
Percentage of sows within each parity that had backfat of less than 17 mm					
Parity 0	3.8	3.9	2.6	-	-
Parity 1	5.9	5.0	7.2	-	-
Parity 2	2.2	4.4	2.6	-	-
Parity 3+	9.7	10.0	9.3	-	-
Daily feed intake, lb	5.9	5.5	5.6	0.17	0.09
Sow weight, lb					
Initial	470.6	460.6	459.5	22.50	0.89
Farrowing	554.4	546.7	541.7	18.21	0.79
Weight gain	84.9	86.5	82.7	10.46	0.94
Estimated post-farrowing[a]	507.9	500.6	496.0	18.21	0.81
Estimated maternal gain, lb[b]	38.4	40.4	37.0	10.46	0.95
Sow backfat, mm					
Service					
Farrowing	13.0	13.2	12.7	0.50	0.53
Backfat gain	14.5	14.4	14.3	0.39	0.85
Predicted					
Maternal weight gain, lb[c]	69.2	57.9	62.5	5.09	0.15
Total weight gain, lb[d]	85.1	86.7	82.9	-	-
Backfat gain, mm[c]	7.3	5.3	6.1	0.90	0.14
Estimated Protein mass, lb[e]					
Initial	79.2	77.1	77.4	4.00	0.86
Farrowing	84.8	83.5	82.8	3.30	0.84
Gain	5.8	6.5	5.5	1.71	0.81
Estimated Fat mass, lb[f]					
Initial	84.0	83.1	80.9	5.39	0.82
Farrowing	96.7	94.6	93.4	3.90	0.68
Gain	12.3	12.7	13.1	3.25	0.95

[a]Farrowing weight – (Total born × 4.1 lb).
[b]Post-farrowing weight – Initial weight.
[c]Predicted based on the actual feed levels provided in gestation (NRC, 1998).
[d]Maternal weight gain plus uterine weight gain (Total born × 4.1 lb).
[e]Prediction equation Dourmad et al. (1997), 2.3 + 0.178 × (liveweight, kg) – 0.33 × (backfat, mm).
[f]Prediction equation Dourmad et al. (1997), -26.40 + 0.221 × (liveweight, kg) + 1.33 × (backfat, mm).

Table 10. Effect of Gestation Feeding Method on Lactation and Subsequent Performance

		Treatment			
Item	Control	Two	Three	SE	P<
Number of sows[a]	179	175	189	-	0.93
Average parity	3.8	4.2	3.9	0.29	0.33
Daily feed intake, lb	13.4	13.3	13.5	0.27	0.70
Sow weight, lb					
Farrowing	580.9	568.8	571.4	5.62	0.08
Weaning	519.4	511.4	513.9	5.80	0.38
Weight loss	60.6	56.0	57.4	3.81	0.49
Estimated post-farrowing[b]	534.3	523.2	524.9	7.40	0.32
Estimated maternal weight loss, lb[c]	14.1	9.9	11.7	3.89	0.59
Estimated protein mass, lb[f]					
Farrowing	85.5	84.3	84.5	1.28	0.60
Weaning	85.4	84.3	84.9	1.04	0.60
Loss	0.1	-0.4	-0.2	0.65	0.78
Estimated fat mass, lb[g]					
Farrowing	118.6	113.1	113.9	2.11	0.06
Weaning	106.2	102.5	101.7	2.70	0.25
Loss	12.3	10.8	12.4	1.45	0.50
Sow backfat, mm					
Farrowing	20.0[d]	19.0[e]	19.1[e]	0.38	0.02
Weaning	16.8	16.2	15.9	0.40	0.07
Loss	3.2	2.8	3.2	0.32	0.40
Total born	11.4	11.3	11.2	0.32	0.78
Born alive	10.6	10.3	10.4	0.32	0.73
Born dead	0.5	0.6	0.5	0.11	0.37
Mummies	0.3	0.3	0.3	0.07	0.80
Fostered[h]	11.0	11.2	11.1	0.11	0.52
Pigs weaned	9.6	9.7	9.8	0.18	0.42
% sows returning estrus in 7 days[a]	95.7	93.8	95.3	-	0.70
Subsequent performance					
Number of sows	141	133	150	-	0.72
Average parity	4.3	4.7	4.5	0.29	0.32
Total born	11.4[d]	11.1[d]	12.3[e]	0.35	0.01
Born alive	10.2[d]	10.1[d]	11.3[e]	0.36	0.01
Born dead	0.9	0.7	0.5	0.14	0.06
Mummies	0.4	0.4	0.4	0.10	0.91
Fallouts[a]	38	42	39	-	0.72

[a]Tested for differences using the chi square analysis.
[b]Farrowing weight – (Total born × 4.1).
[c]Post farrowing weight – weaning weight.
[de]Means with different superscript on the same row differ (P<0.05).
[f]Prediction equation Dourmad et al. (1997), 2.3 + 0.178 × (liveweight, kg) – 0.33 × (backfat, mm).
[g]Prediction equation from Dourmad et al. (1997), -26.40 + 0.221 × (liveweight, kg) + 1.33 × (backfat, mm).
[h]Values represent average litter size 24 hours post-farrowing.

Table 11. Effect of Parity and Backfat at Farrowing on Feed Intake, Performance of Sows in Lactation and Subsequent Performance

	Parity			P2 Backfat at farrowing, mm				P<	
Item	1	2	3+	<17	17-21	> 21	SE	Parity	P2 group
Number of sows[a]	102	117	324	123	258	162	-	0.67	0.16
Average parity	1.0[a]	2.0[b]	5.7[c]	2.9	3.0	2.7	0.22	0.01	0.32
Daily feed intake, lb	11.1[b]	13.4[c]	14.2[d]	13.2[x]	12.9[x]	12.5[y]	0.30	0.01	0.03
Sow weight, lb									
Farrowing	515.7[b]	538.7[c]	601.2[d]	529.6[x]	553.3[y]	572.8[z]	5.69	0.01	0.01
Weaning	456.2[b]	487.3[c]	542.7[d]	479.1[x]	493.9[y]	513.3[z]	6.01	0.01	0.01
Weight loss	60.3	51.1	58.6	50.7	58.7	60.5	4.68	0.13	0.08
Estimated post-farrowing[e]	469.6[b]	492.6[c]	555.1[d]	483.5[x]	507.2[y]	526.6[z]	5.69	0.01	0.01
Estimated maternal weight loss, lb[f]	6.2	2.1	5.5	1.9	5.6	6.3	2.13	0.13	0.08
Estimated protein mass, lb[g]									
Farrowing	74.6[b]	78.9[c]	89.9[d]	80.5	81.4	81.5	1.00	0.01	0.54
Weaning	75.0[b]	80.3[c]	89.7[d]	80.9	81.4	82.7	1.02	0.01	0.14
Loss	-0.37	-1.20	0.16	-0.50	0.00	-0.90	0.79	0.25	0.39
Estimated fat mass, lb[h]									
Farrowing	102.1[b]	106.1[c]	120.5[d]	91.3[x]	109.8[y]	127.7[z]	1.50	0.01	0.01
Weaning	97.8[b]	96.5[c]	109.4[d]	84.6[x]	97.7[y]	111.5[z]	2.00	0.01	0.01
Loss	14.2[b]	9.7[c]	11.3[bc]	6.6[x]	12.0[y]	16.6[z]	0.77	0.05	0.01
Sow backfat, mm									
Farrowing	19.3	18.9	19.1	14.5[x]	19.1[y]	23.7[z]	0.22	0.25	0.01
Weaning	15.6	16.0	16.3	12.7[x]	16.0[y]	19.1[z]	0.40	0.33	0.01
Backfat loss	3.7	2.9	2.9	1.9[x]	3.0[y]	4.6[z]	0.38	0.09	0.01
Total born	11.9[b]	10.2[c]	11.4[b]	11.0	11.2	11.3	0.39	0.01	0.83
Born alive	11.0[b]	9.6[c]	10.5[b]	10.2	10.5	10.4	0.38	0.01	0.62
Born dead	0.4	0.4	0.6	0.5	0.4	0.5	0.13	0.21	0.76
Mummies	0.5[b]	0.2[c]	0.3[c]	0.4	0.3	0.3	0.08	0.01	0.66
Fostered[i]	11.0	11.1	11.2	11.1	11.1	11.0	0.14	0.45	0.66
Pigs weaned	9.8	9.5	9.7	9.8	9.6	9.7	0.21	0.45	0.75
% sows returning 7 days[a]	95.8	93.8	95.2	91.9	95.7	96.1	-	0.79	0.24
Subsequent performance									
Number of sows	92	106	226	93	200	131	-	0.01	0.54
Average parity	2.0[b]	3.0[c]	6.1[d]	3.7	3.8	3.6	0.21	0.01	0.25
Total born	11.6	11.9	11.4	11.8[xy]	12.1[x]	11.1[y]	0.44	0.56	0.02
Born alive	10.6	11.0	10.2	10.7[xy]	11.0[x]	10.0[y]	0.45	0.26	0.02
Born dead	0.6	0.7	0.8	0.7	0.6	0.7	0.17	0.64	0.94
Mummies	0.3	0.2	0.4	0.3	0.4	0.4	0.11	0.28	0.43
Number fallouts[a]	10	11	98	30	58	31	-	0.01	0.54

[a]Tested for differences using the chi square analysis. [bcd]Means with different superscripts on the same row differ (P<0.05). [xyz]Means with different superscripts on the same row differ (P<0.05). [e]Farrowing weight – (Total born × 4.1 lb). [f]Post-farrowing weight –weaning weight. [g]Prediction equation from Dourmad et al. (1997), 2.3 + 0.178 × (liveweight, kg) – 0.33 × (backfat, mm). [h]Prediction equation from Dourmad et al. (1997), -26.40 + 0.221 × (liveweight, kg) + 1.33 × (backfat, mm). [i]Values represent average litter size 24 hours after farrowing.

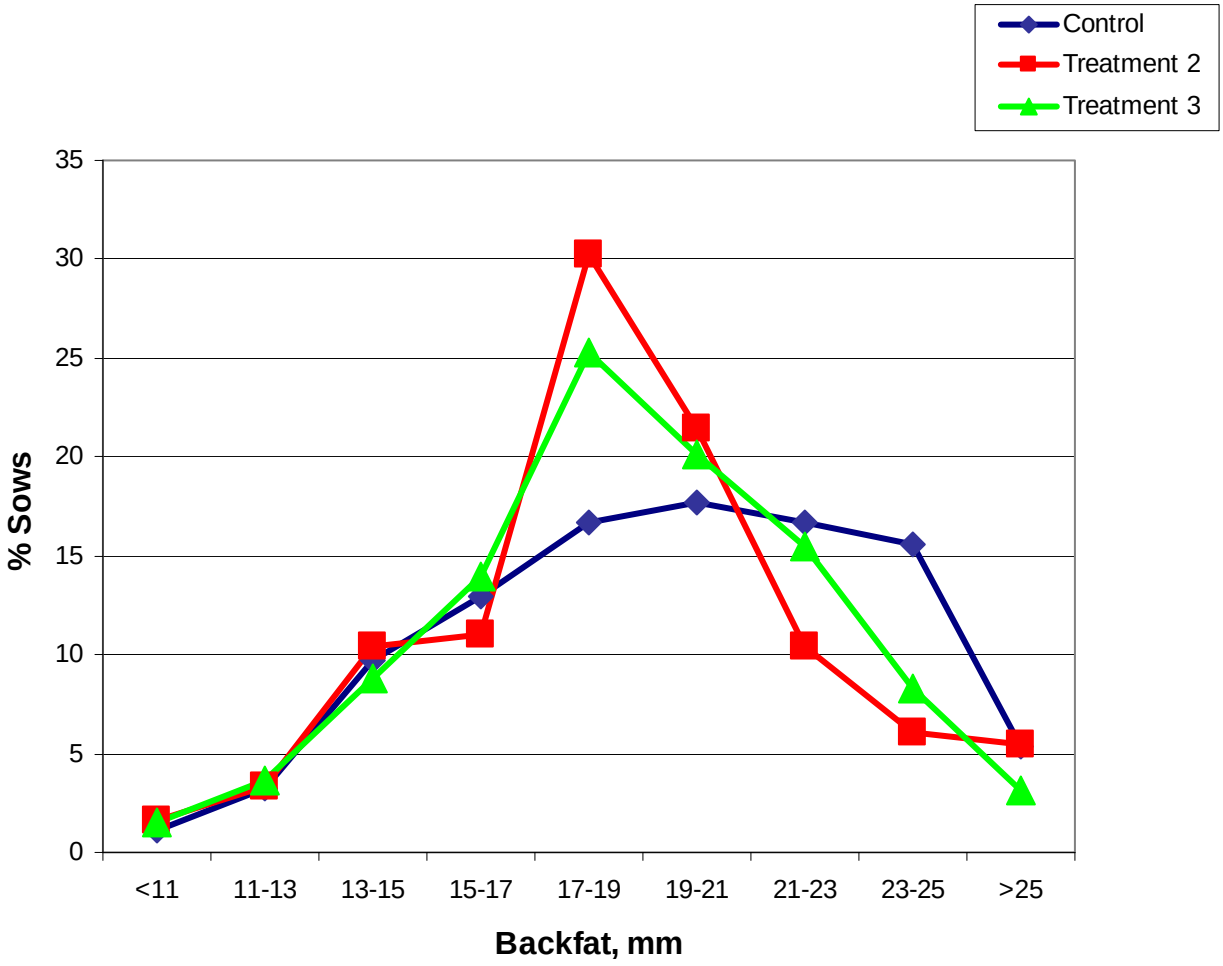

Figure 1. Plot of backfat by percentage of sows at farrowing. Values represent 185 control sows, 180 sows on treatment two, and 194 sows on treatment three.

PELLETED DIETS FOR LACTATING SOWS

E.C. Baudon and J.D. Hancock

Summary

A total of 76 sows (parities one to four) were used to determine the effects of pelleted diets on sow and litter performance. In the 21-d lactation experiment, the sows were given a corn-soybean meal-based diet in meal (corn ground to a particle size of 500 to 600 µm) or a pelleted (3/16 inch pellet diameter) form. Diet form did not affect ADFI or lactation BW loss (P=0.15 or greater). Also, pigs weaned per litter, piglet survivability, litter weight gain, and days to estrus were not affected by treatment (P=0.15 or greater). However, sows fed pelleted feed lost less backfat (0.05 inches, P<0.02). Also, when the diet was pelleted, the sows had 6, 9, and 9% greater digestibilities of DM, N and GE and excretion of DM and N were decreased by 90 g/d and 2 g/d, respectively (P<0.001). In conclusion, use of pelleted feed in mixed-parity sows did not affect litter performance, but increased digestibility of nutrients and reduced nutrient excretion in sows.

(Key Words: Sow, Pellets, Lactation, Digestibility)

Introduction

Previous research from our lab indicated improved rate and especially efficiency of growth in nursery and finishing pigs when diets were fed in pelleted rather than meal form. These marked improvements in growth performance seemed to be at least partly explained by consistent improvements in digestibility of nutrients. In modern sow units, good feed intake and nutrient digestibility are critical for maintaining sow body condition and milk production. However, data concerning the potential benefits of pelleting sow diets are rare. Therefore, we designed an experiment to determine the effects of pelleting lactation diets on performance of sows and their litters.

Procedures

A total of 76 sows (parities one to four) were used in the 21-d lactation experiment. The sows were fed 4 lb/d of a sorghum-based gestation diet until d 110 of pregnancy. The sows were then moved into farrowing crates, randomly assigned to treatment, and given 6 lb/d of the corn-based experimental diets (Table 1) until farrowing. After farrowing they were allowed ad libitum consumption of food and water. The diets were formulated to 1% lysine with all other nutrients in excess of the sow's requirements. Chromium oxide (0.25%) was added as an indigestible marker to allow calculation of nutrient digestibilities. Treatments were the same lactation diet, fed in mash (corn ground to 500 to 600 µm) and a pelleted (3/16" pellet diameter) form. All ingredients were the same for both diets with the only difference being the physical form of the diets.

Within 48 hours after farrowing, the piglets were cross-fostered to equalize litter size among all sows. The sows were weighed and scanned for backfat thickness at farrowing and weaning, and feed and water intakes were recorded. Also, litter size and weight were recorded after cross fostering and at weaning, and duration from weaning to estrus was recorded for each sow.

Each time the diets were processed, a sample of ground corn was collected for determination of particle size. Also, samples of the diets and feces were collected prior to weaning to allow determination of digestibilities of DM, N, and GE. Finally, the Proc Mixed Procedure of SAS was used for statistical analyses of all data.

Table 1. Diet Composition[a]

Ingredient	%
Corn	68.25
Soybean meal	27.25
Monocalcium phosphate	2.00
Limestone	1.10
Salt	0.50
Vitamin premix	0.25
Mineral premix	0.15
Sow add pack	0.25
Chromic oxide	0.25

[a]Formulated to 1% lysine, 0.9% Ca, and 0.8% P.

Results and Discussion

Laboratory analyses indicated that the mean particle size of the corn samples was 503 µm, and the mean particle size of the complete diet before pelleting was 642 µm. Thus, particle size of the ground corn was in the range initially targeted. As for the effects of the diets on sows, diet form did not affect ADFI (P=0.15 or greater) with the average for both treatments near 13 lb/d (Table 2). Lactation BW loss and days to estrus following weaning were not affected by diet form (P=0.15 or greater). However, loss of backfat was reduced by 0.05 in. for the sows fed pelleted diets (P<0.02) while water usage was increased by 1.5 gal/d (P<0.04) among sows fed the pelleted feed.

After cross-fostering, litter size averaged 11 pigs and litter weight averaged 35.7 lb. At weaning the litter averaged 10.2 pigs each with an average weight of 149.5 lb. Diet form did not affect these results, piglet survivability, or litter weight gain during the 21-d experiment (P = 0.15 or greater).

Fecal moisture (Table 3) was not affected by treatments (P=0.15 or greater), but sows fed pelleted feed had 6, 9, and 9% greater digestibilities of DM, N and GE and excretion of DM and N were decreased by 90 g/d and 2 g/d, respectively (P<0.001) compared to sows fed the diet in meal form. Thus, manure volume and nitrogen production would be less problematic for sows fed pelleted feed. Digestibility of GE was increased by 3% (P<0.001) for the sows fed pellets. Therefore those sows would have a better energy balance, thus helping explain the reduced backfat loss for sows fed pelleted feed. However, a better energy balance might also be expected to decrease loss of BW by the sows during lactation, and we did not observe that effect. So, it seems likely nutrient digestibility was a more sensitive measure of nutrient utilization in our experiment.

In conclusion, an important benefit of using pelleted feed is increased digestibility of DM, N and GE. As a result, total output of DM and N as manure are decreased and the potential impact of a swine operation on the environment is reduced. Nonetheless, the primary justification for a producer to use pelleted sow feed is to improve sow and litter performance during lactation and to give a better energy balance that would result in fewer difficulties with thin sows. The pelleting process does increase the cost of processing feed, so this investment must be offset by better litter performance and or body condition of the sow herd. If this cannot be achieved, the use of feed in a mash form is more appropriate.

Table 2. Effects of Pelleted Diets on Sow and Litter Performance

	Diet form			
Item	Mash (600µm)	Pellets (3/16 inch)	SE	P value
Number of sows	38	38		
Sow BW postfarrowing, lb	523	536	8	- [a]
Lactation BW loss, lb	16.2	15.3	4.6	-
Lactation fat loss, in	0.09	0.04	0.02	0.02
ADFI, lb	13.2	13.7	0.4	-
Water disappearance, gal/d	9.2	10.7	0.5	0.04
Initial pigs/litter	10.9	11.0	0.4	-
Pigs weaned/litter	10.3	10.2	0.4	-
Survivability, %	94.1	92.9	1.3	-
Litter weaning wt, lb	150.1	148.8	9.9	-
Litter wt gain, lb	114.3	113.1	9.9	-
Days to estrus	4.6	5.3	0.6	-

Dashes indicate P = 0.15 or greater.

Table 3. Effects of Pelleted Diets on Apparent Digestibility, Intake, and Excretion of Nutrients in Sows

	Diet form			
Item	Mash (600µm)	Pellets (3/16 inch)	SE	P value
Number of sows	38	37		
Fecal moisture, %	70.3	69.2	1.1	0.09
DM intake, kg/d	5.2	5.4	0.1	0.001
N intake, g/d	174	186	1	0.001
GE intake, Mcal/d	23.4	24.7	0.1	0.001
Apparent digestibility,%				
DM	88.2	90.3	0.3	0.001
N	89.5	91.4	0.3	0.001
GE	89.9	92.4	0.3	0.001
Fecal excretion of DM, g/d	617	527	16	0.001
Fecal excretion of N, g/d	18	16	1	0.001

PARTICLE SIZE OF CORN IN LACTATION DIETS FOR MIXED-PARITY SOWS

E.C. Baudon, J.D. Hancock, and M.D. Tokach

Summary

A total of 107 mixed-parity sows (parities one to four) was used to determine the effects of particle size of corn in lactation diets on sow and litter performance. The sows were fed corn-soybean meal-based diets with targeted corn particle sizes of 1,500, 900, and 600 µm (actual means particle sizes of corn during the experiment were 1,600, 824 and 619 µm). Reducing mean particle size of the corn in lactation diets from 1,500 to 600 microns resulted in greater ADFI and water usage (linear effects, P<0.02), fewer days for return to estrus after weaning (linear effect, P<0.04), and less backfat loss (quadratic effect, P<0.03) for the sows.

Although the trends in pigs weaned per litter, piglet survivability, litter weaning weight, and litter weight gain were in the same direction as those for feed intake and water usage in the sows, the difference in measurements of litter performance was not statistically important among treatments (P = 0.15 or greater). Intakes of DM, N, and GE by the sows were increased by 9, 4, and 7% and apparent digestibilities of DM, N, and GE were increased by 6, 5, and 7%, respectively, as particle size of corn was decreased from 1,500 to 600 µm (linear effects, P<0.001). Finally, excretion of DM and N in the feces was decreased (linear effect, P<0.002) by 178 g/d and 5 g/d, respectively, as particle size of the corn on the sow diets was reduced. In conclusion, reducing particle size of corn did not affect litter performance but increased feed intake and digestibility of nutrients and reduced nutrient excretion in sows.

(Key Words: Sow, Particle Size, Lactation, Digestibility)

Introduction

The ever increasing productivity in sows results in greater and greater demand for digestible nutrient intake to support milk production. If this demand is not met by the diet, the sow mobilizes body reserves, which can result in a poor body condition at the end of lactation. Thus, longevity of the sows can be compromised, and turnover rate in the sow herd becomes a costly problem. Data from our lab indicate that reducing particle size of corn from 1,200 to 600 microns in diets for first-litter sows increased feed intake, digestibility of nutrient, and ME content of the feed. However, we continue to field questions about feed intake and performance of older sows when fed diets of small particle sizes. Thus, we designed an experiment to determine the effect of particle size of corn in lactation diets of mixed-parity sows.

Procedure

A total of 107 sows was used in a 21-d lactation experiment. The sows were fed 4 lb/d of a sorghum-based gestation diet for the first 110 days of pregnancy. Then they were moved to a farrowing facility and fed the corn-based experimental diets at 6 lb/d. After farrowing, the sows were allowed ad libitum consumption of feed and water. Cross-fostering was completed among litters within 48 hours after farrowing. Treatments were three corn particle sizes (approximately 1,500, 900, and 600 µm) with the coarsest particle size prepared in a roller mill and the other two

particle size treatments achieved with a hammermill. All other ingredients were the same in all experimental diets (Table 1). Each time the diets were processed, samples of ground corn and the complete diet were collected for particle size determination.

Table 1. Diet Composition[a]

Ingredient	%
Corn	68.25
Soybean meal	27.25
Monocalcium phosphate	2.00
Limestone	1.10
Salt	0.50
Vitamin premix	0.25
Mineral premix	0.15
Sow add pack	0.25
Chromic oxide	0.25

[a]Formulated to 1% lysine, 0.9% Ca, and 0.8% P.

Sows were weighed and scanned for backfat at farrowing and weaning. Water and feed consumption of the sows were recorded each week, and total litter weight and number of pigs were recorded after cross-fostering and at weaning. Finally, samples of feces were collection (one collection per sow) for moisture content and the chromic oxide (0.25%) added to the diets allowed calculation of nutrient digestibilities. All data were analyzed using the Proc Mixed Procedure of SAS with polynomial regression used to describe the shape of the response to reducing particle size in the lactation diets.

Results and Discussion

Analyses of the corn samples collected during the course of the experiment indicated that the particle size was 1,600, 824 and 619 µm for the 1,500, 900 and 600 µm treatments, respectively (Table 2). Thus, the particle sizes were reasonably close to the original targets. By decreasing particle size from the targets of 1,500 to 600 µm, ADFI (Table 3) and water usage were increased by approximately 9 and 42%, respectively (linear effects, $P<0.02$). Loss of backfat thickness for the sow was decreased (quadratic effect, $P<0.03$) as particle size decreased, and the trend for sow BW loss during lactation was in the same direction as that for fat loss, although for BW loss the effect was not statistically significant. Also, measurements of piglet growth and survivability were not different among sows fed diets with different particle sizes ($P=0.15$ or greater).

Table 2. Particle Size Analysis of Corn and Diet

	Particle size, µm		
Item	1,500	900	600
Corn			
No. of observations	7	7	7
Mean particle size	1,600	824	619
Standard deviation	2.21	2.59	2.44
Diet			
No. of observations	7	7	7
Mean particle size	1,282	847	702
Standard deviation	2.17	2.27	2.23

Apparent digestibility of DM and N were improved from 79.9 to 85.0% and 83.0 to 86.7% (linear effects. $P<0.001$) as particle size of corn was reduced from 1,500 to 600 µm (Table 4). These improvements in nutrient digestibility resulted in 19 and 18% decreases in excretion of DM and N (linear effects, $P<0.002$). These improvements in nutrient digestibility are consistent with the general trends in sow and litter performance that suggest better energy balance in the sows fed the diets with the more finely ground corn.

In conclusion, by decreasing particle size of corn we were able to increase water and feed intake. Also, sows fed diets with smaller corn particle sizes had less loss of backfat,

greater digestibilities of DM, N and GE, and returned to estrus more quickly. Thus, use of finely ground corn in lactation diets for multiparous sows is recommended to improve body condition of the sows at weaning and to reduce the environmental impact of swine production.

Table 3. Effects of Corn Particle Size on Sow and Litter Performance

	Particle size, µm				P <	
Item	1,500	900	600	SE	Linear	Quadratic
No. of observations	37	33	35			
Sow BW postfarrowing, lb	556	533	532	12	-[a]	-
Lactation BW loss, lb	23.2	12.4	17.4	8.4	-	-
Lactation fat loss, in	0.09	0.04	0.07	0.01	-	0.03
ADFI, lb	12.1	12.7	13.1	0.4	0.02	-
Water disappearance, gal/d	9.3	12.3	13.2	1.4	0.02	-
Initial pigs/litter	11.3	11.5	11.3	0.3	-	-
Pigs weaned/litter	9.9	10.2	10.4	0.3	-	-
Survivability, %	88.5	89.2	92.0	1.8	-	-
Litter weaning wt, lb	134.3	140.3	140.7	6.8	-	-
Litter wt gain, lb	97.5	102.4	104.5	6.4	-	-
Days to estrus	4.7	4.5	4.2	0.3	0.04	-

[a]Dashes indicate P=0.15 or greater.

Table 4. Effects of Corn Particle Size on Apparent Digestibility, Intake, and Excretion of Nutrients

	Particle size, µm				P <	
Item	1,500	900	600	SE	Linear	Quadratic
No. of observations	37	34	36			
Fecal moisture, %	70.5	70.0	69.8	1.0	-[a]	-
DM intake,kg/d	4.8	5.1	5.3	0.1	0.001	0.001
N intake, g/d	169	176	177	4	0.001	0.12
GE intake, Mcal/d	21.0	22.1	22.8	0.3	0.001	0.005
Apparent digestibility,%						
DM	79.9	83.3	85.0	1.1	0.001	-
N	83.0	85.7	86.8	1.0	0.001	-
GE	80.6	84.5	86.4	1.0	0.001	-
Fecal excretion of DM, g/d	970	844	791	57	0.001	-
Fecal excretion of N, g/d	28	25	23	2	0.002	-

[a]Dashes indicate P=0.15 or greater.

EFFECTS OF INCREASING DIETARY LYSINE IN TRANSITION DIETS ON NURSERY PIG GROWTH PERFORMANCE[1]

J.M. DeRouchey, S.S. Dritz[2], M.D. Tokach, R.D. Goodband, J.L. Nelssen, and J.L. Usry[3]

Summary

A total of 1,400 weanling pigs (initially 13.6 lb) was used in a 9 d growth assay (d 4 to 13 postweaning) to determine the effects of increasing lysine in the transition diet on nursery pig growth performance. All pigs were fed a common SEW diet until d 4 after weaning. Pigs were then switched to experimental diets with total dietary lysine levels of 1.40, 1.50, 1.60, 1.70 or 1.80%. All diets were formulated to contain 20% soybean meal, with increasing amounts of synthetic amino acids to achieve desired amino acid concentrations in the diets. From d 4 to 9 postweaning, increasing lysine increased ADG (linear, P<0.03) and improved feed efficiency (linear, P<0.001), but ADFI was not affected. Overall (d 4 to 13 postweaning), pigs fed diets containing increasing dietary lysine had improved ADG (linear, P<0.03) and feed efficiency (linear, P<0.001), with no differences in ADFI. Although responses to increasing dietary lysine were linear, there was little improvement either ADG or F/G above 1.7% lysine. There was no difference in average pig weight at the end of the trial, probably because of the short duration of the study. In conclusion, increasing dietary lysine up to 1.7% in transition diets (13 to 19 lb) for nursery pigs maximized growth performance.

(Key Words: Nursery Pig, Transition Diet, Lysine Requirement, Growth)

Introduction

Nursery diets are routinely formulated to contain a small amount of soybean meal, yet not as much as to cause digestive complications. When maximum soybean meal levels are reached, other specialty protein products, such as spray-dried animal plasma, blood meal, fishmeal, and spray-dried whey are used to meet the amino acid requirements. However, as levels of these products increase in the diet, diet cost also increases. Another possible means of increasing dietary lysine without using excessive amounts of soybean meal or specialty protein source levels is through the use of crystalline amino acids. Historically, synthetic amino acid use was limited to lysine and methionine because of the high cost of other amino acids. However, recent increased production capabilities have decreased the cost of synthetic threonine, thus providing an economical method of increasing synthetic amino acids in nursery diets. Limited data are available to determine an upper threshold of synthetic amino acid inclusion in nursery diets. Therefore, our objective was to determine the impact of increasing the lysine level in the

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[3]Ajinomoto Heartland Lysine, Chicago, Illinois.

transition diet for nursery pigs through the use of synthetic amino acids (lysine, methionine, and threonine).

Procedures

A total of 1,440 barrows and gilts (initially 13.5 lb and 18 ± 2 d of age) was used in a 9-d growth assay. Pigs were housed in a commercial nursery located in southern Minnesota. At weaning, pigs were randomly sorted into one of 60 pens (30 pens of barrows and 30 pens of gilts) with 24 pigs per pen. Pens of pigs were then weighed and allotted so all pens within each block (six total) were initially the same weight. Two pens of each sex of pigs consumed feed from a single fence line feeder. Thus, the experimental unit was the combined data from the two pens.

All pigs were fed a common SEW diet until d 4 postweaning, then switched to one of five experimental diets with total lysine levels of 1.40, 1.50, 1.60, 1.70, or 1.80%. This period, d 4 to 13 after weaning, corresponds to approximately the same weight range as usage of a transition diet in commercial production. All diets were formulated to contain 20% soybean meal, with increasing amounts of synthetic amino acids to achieve desired experimental levels of amino acids. Experimental diets met or exceeded the nutrient requirements by the NRC (1998). As the dietary lysine level increased, the levels of synthetic methionine, threonine, tryptophan, isoleucine, and valine also increased as needed to maintain minimum ratios relative to lysine (Table 1).

The common SEW diets was formulated to contain 1.70% lysine, and contained 6.7% animal plasma, 5.8% fishmeal, and 1.65% blood meal. Pigs were weighed and feed disappearance determined on d 9 and 13 postweaning for calculation of ADG, ADFI, and F/G.

Data were analyzed using the MIXED procedures of SAS as a randomized complete block design with two pens consuming feed from a single feeder as the experimental unit. Linear and quadratic effects of increasing dietary lysine were determined.

Results and Discussion

From d 4 to 9 postweaning, increasing dietary lysine improved ADG (linear, $P<0.03$) and feed efficiency (linear, $P<0.001$;Table 2). There was no difference in ADFI. Overall (d 4 to 13 postweaning), increasing dietary lysine improved ADG (linear, $P<0.03$) and feed efficiency (linear, $P<0.001$), with no differences in ADFI. Although the responses to ADG and F/G were linear, pig performance was maximized at 1.70% lysine for both. Probably because of the short duration of the trial, the differences in ADG did not result in an overall increase in average pig weight on d 9 or 13.

These data indicate that dietary lysine and other limiting amino acids can be increased through the use of crystalline amino acids and have positive effects on pig growth performance in the transition phase. This may allow nutritionists to increase dietary amino acid levels without increasing the use of high cost specialty protein sources. It would appear that pigs from 13 to 19 lb require approximately 1.7% total lysine to maximize growth performance.

Table 1. Experimental Transition Diets (As-fed Basis)[a]

	Total Dietary Lysine, %				
Ingredient,%	1.40	1.50	1.60	1.70	1.80
Corn	37.80	37.80	37.80	37.80	37.80
Soybean meal, 46.5% CP	20.00	20.00	20.00	20.00	20.00
Spray dried whey	25.00	25.00	25.00	25.00	25.00
Select menhaden fishmeal	6.00	6.00	6.00	6.00	6.00
Spray-dried animal plasma	2.50	2.50	2.50	2.50	2.50
Choice white grease	5.00	5.00	5.00	5.00	5.00
Monocalcium phosphate, 21% P	0.40	0.40	0.40	0.40	0.40
Limestone	0.40	0.40	0.40	0.40	0.40
Salt	0.30	0.30	0.30	0.30	0.30
Vitamin premix	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
Antibiotic[b]	0.125	0.125	0.125	0.125	0.125
L-Isoleucine	0.00	0.024	0.048	0.071	0.095
L-Valine	0.00	0.041	0.083	0.124	0.165
L-Tryptophan	0.00	0.02	0.03	0.05	0.06
L-Threonine	0.025	0.089	0.153	0.216	0.280
L-Lysine HCl	0.018	0.144	0.271	0.398	0.525
DL-Methionine	0.10	0.16	0.22	0.28	0.34
Zinc oxide	0.38	0.38	0.38	0.38	0.38
Acidifier	0.20	0.20	0.20	0.20	0.20
Corn starch	1.36	1.03	0.70	0.37	0.04
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
Total lysine, %	1.40	1.50	1.60	1.70	1.80
Isoleucine:lysine ratio, %	65	63	60	58	56
Leucine:lysine ratio, %	131	123	115	108	102
Methionine:lysine ratio, %	33	35	36	38	39
Met & Cys:lysine ratio, %	60	60	60	60	60
Threonine:lysine ratio, %	69	68	68	68	67
Tryptophan:lysine ratio, %	19	19	19	19	18
Valine:lysine ratio, %	75	73	71	69	68
ME, kcal/lb	1,599	1,598	1,597	1,596	1,595
Lysine:calorie ratio, g/mcal	3.97	4.26	4.55	4.83	5.12
Crude protein, %	21.3	21.3	21.3	21.3	21.3
Ca, %	0.81	0.81	0.81	0.81	0.81
P, %	0.73	0.73	0.73	0.73	0.73
Available P, %	0.52	0.52	0.52	0.52	0.52

[a]All pigs were fed a common SEW diet (1.7% lysine) from weaning to day 4, then fed the experimental diets from d 4 to 13 post-weaning.
[b]Provided Denegard (35 g/ton) and chlortetracycline (600 g/ton).

Table 2. Effects of Increasing Dietary Lysine in Transition Diets on Nursery Pig Growth Performance[a]

	Total dietary lysine, %						P<	
Item	1.40	1.50	1.60	1.70	1.80	SE	Linear	Quadratic
Day 4 to 9								
ADG, lb	0.42	0.40	0.47	0.47	0.45	0.03	0.03	0.43
ADFI, lb	0.40	0.37	0.39	0.38	0.37	0.02	0.31	0.99
F/G	0.94	0.93	0.84	0.82	0.82	0.04	0.001	0.34
Day 4 to 13								
ADG, lb	0.59	0.60	0.59	0.63	0.64	0.020	0.001	0.44
ADFI, lb	0.59	0.57	0.57	0.57	0.57	0.014	0.55	0.33
F/G	1.00	0.95	0.98	0.91	0.90	0.027	0.001	0.95
Pig weight, lb								
Day 4	13.6	13.6	13.6	13.6	13.6	0.26	0.94	0.93
Day 9	15.7	15.6	16.0	15.9	15.9	0.31	0.34	0.81
Day 13	18.9	18.9	18.9	19.3	19.3	0.37	0.15	0.66

[a]A total of 1,440 pigs (6 observations/treatment with 2 pens of 24 pigs and a single fenceline feeder per observation) was used in the experiment.

EFFECTS OF INCREASING DIETARY LYSINE IN PHASE II DIETS (15- TO 25-LB) ON NURSERY PIG GROWTH PERFORMANCE

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Summary

A total of 1,260 weanling pigs (initially 18.6 lb) was used in a 19 d growth assay (d 10 to 29 after weaning) to determine the effects of increasing lysine in Phase II diets on nursery pig growth performance. All pigs were weaned and fed 1.2 lb per pig of a SEW diet, then switched to a transition diet until day 10 after weaning. Pigs were then weighed and switched to experimental diets containing true digestible lysine levels of 1.22, 1.32, 1.42, 1.52, and 1.62%, corresponding to approximately 1.36, 1.47, 1.56, 1.65, and 1.75% total lysine. All diets were formulated to contain 30% soybean meal, with increasing amounts of synthetic amino acids to achieve desired amino acid concentrations in the diets. From d 10 to 17 after weaning, increasing lysine increased ADG (quadratic, $P<0.04$) and improved feed efficiency (quadratic, $P<0.01$), with both appearing to be maximized at 1.52% true ileal digestible lysine. From d 17 to 24 and 24 to 29, ADFI and F/G improved (linear, $P<0.05$) with increasing true ileal digestible lysine. For the overall study, (d 10 to 29 after weaning), increasing true ileal digestible lysine increased ADG (quadratic, $P<0.07$) and improved feed efficiency (quadratic, $P<0.001$). In conclusion, 1.52% true ileal digestible lysine maximized both ADG and F/G early in the study, but the lysine requirement appeared to decrease to 1.42% from d 17 to 24. Results of two recent studies conducted at the University of Missouri with similar lysine levels fed to 15- to 25-lb pigs suggest a requirement estimate between 1.32 and 1.42% true ileal digestible lysine, slightly lower than the requirements observed in the present study.

(Key Words: Nursery Pig, Phase II, Lysine Requirement, Growth)

Introduction

In a previous lysine titration study for 25- to 45-lb pigs, we found that dietary lysine requirements appear to be much higher than previously estimated. In fact, the requirements for 25- to 45-lb pigs are greater than levels currently fed to pigs from 15 to 25 lb. In addition to better growth performance, feeding additional dietary lysine resulted in improved margin over feed costs and lowered feed cost per lb of gain. As pigs grow, their feed intake increases, and the lysine requirement expressed as a percentage of the diet decreases. Therefore, from these previous studies, we suspect that lysine levels currently fed to 15- to 25-lb pigs may be too low. Therefore, our objective was to determine the optimum lysine level for pigs fed from 15 to 25 lb.

[1]Food Animal Health and Management Center.

Procedures

A total of 1,260 weanling pigs (initially 18.6 lb) was used in a 19 d growth assay (d 10 to 29 after weaning) to determine the effects of increasing lysine in Phase II diets on nursery pig growth performance. Pigs were housed in a commercial nursery in southern Minnesota. At weaning, pigs were randomly sorted into one of 60 pens (30 pens of barrows and 30 pens of gilts) with 21 pigs per pen. All pigs were weaned and fed 1.2 lb per pig of a SEW diet, and then switched to a transition diet until day 10 after weaning. Pigs were then weighed and switched to experimental diets containing true digestible lysine levels of 1.22, 1.32, 1.42, 1.52, and 1.62%, corresponding to approximately 1.36, 1.47, 1.56, 1.65, and 1.75% total lysine. All diets were formulated to contain 30% soybean meal, with increasing amounts of synthetic amino acids to achieve desired amino acid concentrations in the diets. Experimental diets met or exceeded the nutrient requirements of the NRC (1998). As the dietary lysine level increased, the levels of synthetic methionine, threonine, tryptophan, isoleucine, and valine also increased as needed to maintain minimum ratios relative to lysine (Table 1).

The common SEW diet was formulated to contain 1.70% lysine, and contained 6.7% animal plasma, 5.8% fishmeal, and 1.65% blood meal. The transition diet was formulated to contain 1.55% lysine and contained 2.5% animal plasma and 6% fishmeal. Pigs were weighed and feed disappearance determined at the start of the study on d 10, and on d 17, 24, and 29 for calculation of ADG, ADFI, and F/G.

Data were analyzed using the PROC MIXED procedures of SAS as a randomized complete block design, with two pens consuming feed from a single feeder as the experimental unit. Linear and quadratic effects of increasing dietary lysine were determined.

Results and Discussion

From d 10 to 17, increasing true ileal digestible lysine improved (quadratic, $P<0.04$) ADG and F/G. It appeared that 1.52% true ileal digestible lysine maximized both ADG and F/G for this period corresponding to 18 to 23 lb. Average daily feed intake tended to increase (linear, $P<0.07$) with increasing true ileal digestible lysine.

From d 17 to 24, increasing true ileal digestible lysine increased (linear $P<0.01$) ADG and improved (quadratic $P<0.06$) F/G. During this period, it appeared that 1.42% true ileal digestible lysine was sufficient for both ADG and F/G.

From d 24 to 29, both ADG and F/G increased (linear $P<0.01$) with increasing true ileal digestible lysine.

For the overall experimental period (d 10 to 29 after weaning), increasing true ileal digestible lysine improved ADG (quadratic, $P<0.07$) and F/G (quadratic, $P<0.01$). Average daily feed intake was unaffected ($P>0.41$) by increasing true ileal digestible lysine. Average pig weight taken on each weigh day during the study increased (linear, $P<0.01$) with increasing true ileal digestible lysine. It appeared that 1.52% true ileal digestible lysine maximized both ADG and F/G early in the study, but then the lysine requirement appeared to decrease to 1.42% from d 17 to 24. Results of two recent studies conducted at the University of Missouri with similar lysine levels fed to 15- to 25-lb pigs suggest a requirement estimate between 1.32 and 1.42% true ileal digestible lysine, just slightly lower than the requirements observed in the present study. Current lysine recommendations for pigs of this weight are much lower than ob-

served in both our study and those conducted by the University of Missouri. Calculating the expected value of the added weight gain from increasing dietary lysine ($0.40/lb) and current ingredient prices, feeding diets containing 1.42% true ileal digestible lysine (approximately 1.56% total lysine) will decrease feed cost per pig by $0.05 to $0.10 per pig and increase margin over feed cost (profit) by $0.20 to $0.30 per head.

Table 1. Experimental Phase II Diets (As-fed Basis)[a]

	True ileal digestible lysine, %				
Ingredient,%	1.22	1.32	1.42	1.52	1.62
Corn	50.39	50.13	49.87	49.53	49.13
Soy bean meal 48% CP	30.00	30.00	30.00	30.00	30.00
Lactose	7.00	7.00	7.00	7.00	7.00
Select menhaden fishmeal	6.67	6.67	6.67	6.67	6.67
Choice white grease	3.00	3.00	3.00	3.00	3.00
Dicalcium phosphate (18.5% P)	0.88	0.88	0.89	0.88	0.88
Limestone	0.33	0.33	0.33	0.33	0.33
Salt	0.40	0.40	0.40	0.40	0.40
DL-Methionine	0.05	0.12	0.18	0.24	0.30
L-Lysine HCl	---	0.13	0.26	0.38	0.51
L-Threonine	0.04	0.10	0.17	0.24	0.30
L-Tryptophan	---	---	---	0.02	0.04
L-Isoleucine	---	---	---	---	0.06
L-Valine	---	---	---	0.07	0.14
Zinc oxide	0.25	0.25	0.25	0.25	0.25
Vitamin & trace mineral premix	0.30	0.30	0.30	0.30	0.30
Medication	0.70	0.70	0.70	0.70	0.70
Total	100.00	100.00	100.00	100.00	100.00
Calculated analysis					
Total lysine, %	1.36	1.47	1.56	1.65	1.75
ME, kcal/lb	1,562	1,564	1,565	1,566	1,568
Crude protein %	22.63	22.81	23.00	23.25	23.53
Ca, %	0.80	0.80	0.80	0.80	0.80
Available P, %	0.40	0.40	0.40	0.40	0.40
True ileal digestible amino acid ratios					
Lysine, g/ Mcal ME	3.54	3.83	4.11	4.40	4.68
Methionine:Lysine, %	35	37	38	40	41
Met+Cys:Lysine, %	60	60	60	60	60
Threonine:Lysine, %	65	65	65	65	65
Tryptophan:Lysine, %	20	18	17	17	17
Isoleucine:Lysine, %	70	65	60	56	56
Valine:Lysine, %	78	72	67	67	67

[a]All pigs were fed 1.2 lb of common SEW diet (1.7% lysine) followed by the transition diet (1.65% lysine) to day 10. The experimental diets were fed from d 10 to 19 after weaning.

Table 2. Effects of Increasing Lysine in Phase II Diets on Nursery Pig Growth Performance[a]

	True ileal Digestible Lysine, %						P<	
Item	1.22	1.32	1.42	1.52	1.62	SEM	Linear	Quadratic
Day 10 to 17								
ADG, lb	0.54	0.62	0.64	0.69	0.68	0.02	0.01	0.04
ADFI, lb	0.86	0.89	0.88	0.92	0.90	0.02	0.07	0.58
F/G	1.62	1.44	1.37	1.33	1.33	0.04	0.01	0.01
Day 17 to 24								
ADG, lb	1.00	1.08	1.11	1.11	1.13	0.03	0.01	0.13
ADFI, lb	1.42	1.42	1.45	1.44	1.43	0.02	0.47	0.53
F/G	1.42	1.31	1.30	1.29	1.27	0.02	0.01	0.06
Day 24 to 29								
ADG, lb	1.27	1.35	1.28	1.34	1.36	0.03	0.04	0.98
ADFI, lb	1.94	1.90	1.89	1.96	1.91	0.03	0.97	0.65
F/G	1.53	1.42	1.48	1.46	1.41	0.02	0.02	0.58
Day 10 to 29								
ADG, lb	0.94	1.02	1.01	1.05	1.06	0.02	0.01	0.07
ADFI, lb	1.41	1.41	1.41	1.44	1.42	0.02	0.41	0.86
F/G	1.53	1.39	1.39	1.36	1.34	0.01	0.01	0.01
Pig weight, lb								
Day 10	18.7	18.6	18.6	18.6	18.7	0.3	--	--
Day 17	22.4	23.0	23.1	23.4	23.4	0.3	0.01	0.41
Day 24	29.4	30.6	30.9	31.2	31.4	0.4	0.01	0.27
Day 29	35.9	37.3	37.3	37.9	38.2	0.4	0.01	0.38

[a]A total of 1,260 pigs (5 observations/treatment with 2 pens of 21 pigs and a single fenceline feeder per observation) were used in the experiment.

EFFECTS OF INCREASING CRYSTALLINE AMINO ACIDS AND THE SUBSEQUENT CHANGE IN DIET NET ENERGY ON GROWING PIG PERFORMANCE[1]

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Summary

Three individual trials were conducted to evaluate the effect of increasing the amount of crystalline amino acids (L-lysine, L-threonine, and DL-methionine) as a replacement for soybean meal in the diet on pig growth performance. A second objective was to determine if increasing net energy (NE) concentration in the diet as a result of increased crystalline amino acids and less soybean meal would affect pig growth. In all three studies, pigs (each approximately 21 lb) were fed a corn-soybean meal diet, or diets with 2, 4, 6, or 8 lb/ton L-lysine HCl and other amino acids to maintain their proper ratio relative to lysine. In Experiments 1 and 3, added fat level was constant at 1%. In Experiment 2, the fat level was reduced slightly as amino acids replaced soybean meal to account for the slight change in ME as synthetic amino acids were added to the diet.

In Experiment 1, increasing L-lysine and other crystalline amino acids had no effect on ADG, but F/G improved (linear, $P<0.05$). In Experiment 2, ADG tended (linear, $P<0.09$) to increase and F/G improved (quadratic, $P<0.04$) with increasing L-lysine. In Experiment 3, ADG and ADFI tended ($P<0.09$) to increase with increasing L-lysine HCl, but F/G was unchanged. In summary, these results indicate that in the young pig, up to 8 lb of L-lysine HCl with other amino acids to maintain a proper ratio relative to lysine are effective replacements for soybean meal in the diet. Furthermore, when replacing soybean meal with crystalline amino acids, feed efficiency improvements are correlated with changes in the diet's net energy concentration. Using ME to calculate the energy value of low-protein amino acid fortified diets will tend to underestimate the diet's actual energy value.

(Key Words: Pigs, Growth, Net Energy, Amino Acids)

Introduction

In 2002, the first production facility dedicated to manufacturing L-threonine was opened in the United States. As a result, L-threonine, like L-lysine HCl and DL methionine, has become more widely available and less expensive for use in swine diets. If economically feasible, the use of L-threonine would allow for greater amounts of L-lysine use than the typical 3 lb/ton inclusion. Use of

[1]The authors would like to thank Ajinomoto Heartland LLC, Chicago, Illinois, for providing the crystalline amino acids and partial financial support for this study.
[2]Mid-West Co-op.
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higher levels of synthetic amino acids will have environmental advantages by further decreasing nitrogen concentration in swine waste by 20% or more. Another possible advantage of low-protein crystalline amino acid fortified diets is an increase in the NE content of the diet. Typically in swine diets, ME is used as a measure of energy content of an ingredient. Metabolizable energy is the gross energy of the feed ingredient minus the energy that is lost through digestion (feces), as well as that lost in urine and gas. Net energy takes into account an ingredient's ME, but in addition also takes into account energy lost as heat in the process of digestion. Net energy is frequently used to describe the energy content of ingredients for ruminants.

Soybean meal and corn have a similar energy content on an ME basis. However, soybean meal has a lower energy content based on an NE basis because of its high protein content. Thus, diets formulated with synthetic amino acids should have a higher NE content than those formulated with soybean meal. Using synthetic amino acids will not affect the ME content of the diet. Therefore, pigs fed diets formulated with a similar ME content but increasing amounts of synthetic amino acids should have increased growth rate and improved feed efficiency. The objective of these studies was to verify the efficiency of utilization of crystalline amino acids relative to soybean meal, and a second objective was to evaluate methods of expressing energy (ME versus NE) when using a low crude protein-high crystalline amino acid diet.

Procedures

Three individual 21-d trials were conducted in commercial nurseries with pigs approximately 21 days after weaning. Experiments 1 and 2 were conducted in the same nursery facility in southern Minnesota and Experiment 3 was conducted in a facility in Illinois. In all three studies, pigs (each approximately 21 lb) were fed a corn-soybean meal diet, or diets with 2, 4, 6, or 8 lb/ton of L-lysine HCl and other amino acids to maintain their proper ratio relative to lysine (Tables 1, 2, and 3).

Diets in Experiments 1 and 2 were formulated to 1.36% true ileal digestible lysine. In Experiment 3, diets were formulated to 1.29% true ileal digestible lysine. Minimum true digestible amino acid ratios relative to lysine were maintained in all diets with minimum ratios set at 30% for methionine, 60% for methionine and cystine, 65% for threonine, and 16.5% for tryptophan. In Experiments 1 and 3, added fat was maintained constant at 1% of the diet. Corn and soybean meal levels were adjusted as synthetic amino acids were added to the diet. In Experiment 2, the fat level in the diet was reduced from 1% to 0.25% of the diet as increasing synthetic amino acids were added to the diet in an attempt to maintain a constant modified ME level. In modified ME, the energy value for all ingredients except soybean meal is the same as given by NRC (1998). The energy value for soybean meal (3,181 versus 3,380 kcal/kg for NRC) is lower in modified ME in an attempt to account for the lower net energy value of high protein ingredients like soybean meal. Net energy values used in diet calculations were derived from those published by Noblet et al. (2002).

In Experiment 1, 1,440 pigs were used with 60 pens (30 pens of barrows and 30 pens of gilts) and 24 pigs per pen. Two pens (same sex) of pigs consumed feed from a single fence line feeder. Thus, the experimental unit was the combined data from the two pens and provided six observations per treatment. Pens of pigs and feeders were weighed on d 21 (allotment day) and d 28, 35, and 42 after weaning to calculate ADG, ADFI and F/G. In addition, gain/feed ratio (G/F), the inverse of F/G was calculated for modeling the change in efficiency with either the ME or NE content of the diet. In Experiment 2, we repeated the same procedures. Experiment 3 was also conducted in a similar manner, with the exception

that pigs were started on test when they averaged approximately 25 lb. There were 21 pigs per pen with two pens sharing a common feeder. Thus, there were 42 pigs per experimental unit. There were six replications. Pens of pigs were weighed at allotment and 21 days later at completion of the experiment. Feed disappearance also was measured to calculate ADG and feed efficiency.

Data were analyzed using the PROC MIXED procedures of SAS as a randomized complete block design with two pens consuming feed from a single feeder as the experimental unit. Linear and quadratic effects of increasing L-lysine HCl were determined.

Results and Discussion

In Experiment 1, increasing L-lysine HCl did not affect (P>0.10) growth rate (Table 4). However, feed intake tended (linear, P<0.09) to decrease with increasing L-lysine HCl. Feed efficiency improved (linear, P<0.04) as more synthetic L-lysine HCl was added to the diet at the expense of soybean meal. The calculated change in ME content of the diet containing no L-lysine HCl and the diet containing 8-lb/ton lb diet was 0.3%. The corresponding change in calculated NE of the diets was 3.7%. The change in calculated modified ME was 0.8%. The improvement in feed efficiency was approximately 2% indicating that ME and modified ME underestimate the energy value, while NE overestimates the energy value of low crude protein diets containing high levels of synthetic amino acids.

In Experiment 2, ADG tended (linear, P<0.09) to increase and F/G improved (quadratic, P<0.04) with increasing L-lysine (Table 5). When evaluating the energetic efficiency of gain (Mcal of energy required for every kg of gain), energetic efficiency of gain improved (quadratic, P<0.04) as synthetic amino acids were added to the diet when using ME or modified ME values, suggesting these systems underestimate the actual energy value of the diet. When energetic efficiency of gain was compared using the NE system, energetic efficiency of gain improved (linear, P<0.03) suggesting that the NE values overestimated the actual energy value of the diet as synthetic amino acids replaced soybean meal. Feed cost per lb of gain improved slightly (quadratic, P<0.04) as 2 or 4 lb of Lysine HCl with added methionine and threonine replaced soybean meal in the diet. However, feed cost at the higher inclusion rates of amino acids was similar to the feed cost for pigs fed the control diet. Margin over feed cost was not influenced by the level of synthetic amino acids added to the diets.

In Experiment 3, ADG and ADFI tended (P<0.09) to increase with increasing levels of synthetic amino acids, but F/G was unchanged (Table 6). The improvement in ADG again indicates that utilizable energy increased as levels of synthetic amino acids increased in the diet. These data again would suggest that the ME system underestimates the energy value of the diet. An interesting finding in this study was that the number of pigs that were treated (measured as injections per pen) was reduced as higher levels of synthetic amino acids were added and soybean meal level was reduced. Additional studies need to be conducted to verify and confirm this observation.

Results of these trials demonstrate that up to 8 lb/ton of L-lysine HCl and other crystalline amino acids to maintain their proper ratio relative to lysine can effectively replace soybean meal and provide similar if not better pig performance. Furthermore, these studies also demonstrate that the NE content of the diet increases as more crystalline amino acids are added to the diet as reflected by improvements in feed efficiency. Our results would indicate that the NE values for ingredients derived by Noblet et al. (2002) slightly overestimate the actual NE increase while the ME values from NRC (1998) or the Modified ME method underestimate the energy value of diets containing high levels of synthetic amino acids. The

NE values of Noblet et al. (2002) suggest that the energy value of soybean meal is 75% of the energy value of corn. The ME value from NRC (1998) or the modified ME value would suggest the energy value of soybean meal is 99 or 93% of the value of energy in corn. The results of these experiments suggest the energy value of soybean meal is 85 to 88% (average of 86%) of the energy value of corn, midway between the NE and ME values.

Table 1. Diet Composition (Experiment 1, As-fed Basis)

	L-lysine HCl, lb/ton				
Ingredient, %	0	2	4	6	8
Corn	48.99	51.93	54.86	57.80	60.74
Soybean meal, 46.5 CP%	46.41	43.30	40.19	37.08	33.96
Choice white grease	1.00	1.00	1.00	1.00	1.00
Dicalcium phosphate, 18.5% P	1.40	1.40	1.40	1.40	1.40
Limestone	0.75	0.75	0.75	0.75	0.75
Salt	0.35	0.35	0.35	0.35	0.35
Vitamins and trace minerals	0.30	0.30	0.30	0.30	0.30
L-Threonine	0.02	0.07	0.11	0.16	0.20
Antibiotic[a]	0.70	0.70	0.70	0.70	0.70
Lysine HCl	0.00	0.10	0.20	0.30	0.40
DL-Methionine	0.08	0.11	0.14	0.17	0.20
Total	100.00	100.00	100.00	100.00	100.00
Total lysine, %	1.53	1.52	1.51	1.51	1.50
True ileal digestibility, %					
Lysine	1.36	1.36	1.36	1.36	1.36
Isoleucine:lysine ratio	74.3	70.5	66.6	62.7	58.9
Leucine:lysine ratio	143.9	138.4	132.9	127.4	122.0
Methionine:lysine ratio	32.1	33.2	34.4	35.5	36.6
Met & Cys:lysine ratio	60.0	60.0	60.0	60.0	60.0
Threonine:lysine ratio	64.9	65.0	65.1	65.2	65.3
Tryptophan:lysine ratio	21.8	20.5	19.3	18.1	16.9
Valine:lysine ratio	80.3	76.5	72.6	68.8	65.0
ME, kcal/lb	1,510	1,511	1,513	1,514	1,515
NE, kcal/lb	1,044	1,054	1,063	1,073	1,083
Modified ME, kcal/lb	1,464	1,467	1,470	1,474	1,477
Protein, %	0.75	0.74	0.73	0.72	0.71
Ca, %	0.72	0.70	0.69	0.68	0.66
P, %	0.35	0.35	0.34	0.34	0.34
Available P, %	0.43	0.43	0.42	0.42	0.42

[a]Provided 140 g/ton of neomycin and 140 g/ton of terramycin.

Table 2. Diet Composition (Experiment 2, As-fed Basis)

	L-lysine HCl, lb/ton				
Ingredient, %	0	2	4	6	8
Corn	48.99	52.12	55.25	58.39	61.52
Soybean meal, 46.5 CP%	46.41	43.29	40.17	37.05	33.93
Choice white grease	1.00	0.81	0.63	0.44	0.25
Dicalcium phosphate, 18.5% P	1.40	1.40	1.40	1.40	1.40
Limestone	0.75	0.75	0.75	0.75	0.75
Salt	0.35	0.35	0.35	0.35	0.35
Vitamins and trace minerals	0.30	0.30	0.30	0.30	0.30
L-Threonine	0.02	0.07	0.11	0.16	0.20
Antibiotic[a]	0.70	0.70	0.70	0.70	0.70
Lysine HCl	0.00	0.10	0.20	0.30	0.40
DL-Methionine	0.08	0.11	0.14	0.17	0.20
Total	100.00	100.00	100.00	100.00	100.00
Total lysine, %	1.53	1.52	1.51	1.51	1.50
True ileal digestibility, %					
Lysine	1.36	1.36	1.36	1.36	1.36
Isoleucine:lysine ratio	74.3	70.5	66.6	62.8	58.9
Leucine:lysine ratio	143.9	138.5	133.1	127.7	122.3
Methionine:lysine ratio	32.1	33.3	34.4	35.5	36.7
Met & Cys:lysine ratio	60.0	60.0	60.0	60.1	60.1
Threonine:lysine ratio	64.9	65.0	65.2	65.3	65.4
Tryptophan:lysine ratio	21.8	20.5	19.3	18.1	16.9
Valine:lysine ratio	80.3	76.5	72.7	68.9	65.1
ME, kcal/lb	1,510	1,508	1,505	1,502	1,500
NE, kcal/lb	1,044	1,050	1,056	1,062	1,068
Modified ME, kcal/lb	1,464	1,464	1,464	1,464	1,464
Protein, %	0.75	0.74	0.73	0.72	0.71
Ca, %	0.72	0.70	0.69	0.68	0.67
P, %	0.35	0.35	0.34	0.34	0.34
Available P, %	0.43	0.43	0.42	0.42	0.42

[a]Provided 140 g/ton of neomycin and 140 g/ton of terramycin.

Table 3. Diet Composition (Experiment 3, As-fed Basis)

	L-lysine HCl, lb/ton				
Ingredient, %	0	2	4	6	8
Corn	52.22	55.12	58.02	60.92	63.82
Soybean meal, 46.5 CP%	43.55	40.44	37.33	34.22	31.12
Choice white grease	1.00	1.00	1.00	1.00	1.00
Dicalcium phosphate, 18.5% P	1.48	1.50	1.52	1.53	1.55
Limestone	1.00	1.02	1.04	1.05	1.07
Salt	0.35	0.35	0.35	0.35	0.35
Vitamins and trace minerals	0.25	0.25	0.25	0.25	0.25
Copper sulfate	0.08	0.08	0.08	0.08	0.08
L-Threonine	0.01	0.06	0.10	0.15	0.19
Lysine HCl	0.00	0.10	0.20	0.30	0.40
DL-Methionine	0.06	0.09	0.12	0.15	0.19
Total	100.00	100.00	100.00	100.00	100.00
Total lysine, %	1.45	1.44	1.44	1.43	1.42
True ileal digestibility, %					
Lysine	1.29	1.29	1.29	1.29	1.29
Isoleucine:lysine ratio	74.8	70.7	66.6	62.5	58.4
Leucine:lysine ratio	146.9	141.1	135.3	129.5	123.7
Methionine:lysine ratio	31.7	32.9	34.1	35.3	36.5
Met & Cys:lysine ratio	60.0	60.0	60.1	60.1	60.1
Threonine:lysine ratio	65.0	65.0	65.1	65.1	65.1
Tryptophan:lysine ratio	21.8	20.5	19.2	17.9	16.6
Valine:lysine ratio	81.1	77.1	73.0	69.0	64.9
ME, kcal/lb	1,516	1,517	1,517	1,518	1,519
NE, kcal/lb	1,056	1,066	1,075	1,084	1,094
Modified ME, kcal/lb	1,472	1,475	1,478	1,480	1,483
Protein, %	0.85	0.86	0.86	0.86	0.86
Ca, %	0.72	0.71	0.70	0.69	0.68
P, %	0.36	0.36	0.36	0.36	0.36
Available P, %	0.43	0.43	0.43	0.43	0.43

Table 4. Effect of Replacing Soybean Meal with Synthetic Amino Acids on Pig Performance, Experiment 1[a]

	L-lysine HCl, lb/ton							Probabilty, P<	
Item	0	2	4	6	8	SED	Model	Linear	Quadratic
ADG, lb	1.29	1.28	1.27	1.27	1.27	0.029	0.93	0.63	0.64
ADF, lb	1.91	1.90	1.85	1.88	1.85	0.035	0.32	0.09	0.57
F/G	1.49	1.48	1.46	1.48	1.45	0.015	0.19	0.05	0.99
Gain:Feed	0.673	0.675	0.684	0.678	0.688	0.007	0.17	0.04	0.98
Day 21 wt, lb	50.6	50.5	50.2	50.3	50.4	0.6	0.96	0.72	0.59
Feed cost, $/lb of gain[b]	$ 0.107	$ 0.108	$ 0.107	$ 0.109	$ 0.107	$ 0.001	0.65	0.79	0.99

[a]Each value is the mean of six experimental units with 48 pigs per experimental unit (24 pigs per pen with 2 pens sharing a common feeder as the experimental unit).

[b]Diet costs were calculated using: $2.24/bu corn, $170/ton soybean meal, $0.90/lb Lysine HCl, $1.35/lb threonine, and $1.20/lb methionine. The five treatment diets were each formulated to contain similar lysine, threonine, and methionine content. Thus, the diets with more synthetic lysine contained less soybean meal. Note that as more synthetic amino acids are used, diet cost increases by about $0.80 per ton.

Table 5. Effect of Replacing Soybean Meal with Synthetic Amino Acids on Pig Performance, Experiment 2[a]

	L-lysine HCl, lb/ton						P-value		
Item	0	2	4	6	8	SEM	Treatment	Linear	Quad
ADG, lb	1.11	1.14	1.12	1.13	1.16	0.017	0.28	0.09	0.66
ADF, lb	1.62	1.62	1.60	1.64	1.68	0.023	0.14	0.06	0.09
F/G	1.46	1.42	1.43	1.45	1.44	0.013	0.10	0.83	0.04
Energetic efficiency, Mcal/kg gain									
ME	4.85	4.70	4.72	4.78	4.76	0.04	0.08	0.36	0.04
Modified ME	4.72	4.59	4.62	4.68	4.67	0.04	0.10	0.84	0.04
Noblet NE	3.35	3.28	3.31	3.38	3.39	0.03	0.03	0.04	0.04
Weight, lb									
Day 0	21.3	21.7	21.6	21.3	21.5	0.5	0.69	0.81	0.52
Day 21	44.7	45.6	45.1	45.2	45.9	0.7	0.47	0.22	0.96
Feed cost, $/lb of gain	$0.107	$0.104	$0.105	$0.107	$0.107	$0.001	0.09	0.53	0.04
Margin over feed, $/pig	$ 6.85	$ 7.08	$ 6.94	$ 7.00	$ 7.16	$ 0.12	0.43	0.18	0.91

[a]Each value is the mean of six experimental units with 48 pigs per experimental unit (24 pigs per pen with 2 pens sharing a common feeder as the experimental unit).

Table 6. Effect of Replacing Soybean Meal with Synthetic Amino Acids on Pig Performance, Experiment 3[a]

	L-lysine HCl, lb/ton					P-values			
	0	2	4	6	8	Treatment	Linear	Quad	S.E.
ADG, lb	1.15	1.15	1.20	1.22	1.18	.19	.09	---	.024
ADFI, lb	1.72	1.76	1.82	1.83	1.79	.16	.06	---	.035
F/G	1.49	1.53	1.52	1.51	1.51	.80	---	---	.021
Initial wt, lb	26.9	26.8	26.7	26.9	26.9	.99	---	---	.511
Day 21 wt, lb	51.5	51.7	51.9	52.6	52.0	.86	---	---	.765
Margin over feed, $/pig	8.89	8.97	9.03	9.25	9.03				
Injections per pen[b]	6.3	7.5	4.5	2.3	4.2	.06	.03	---	1.22

[a]Each value is the mean of six experimental units with 42 pigs per experimental unit (21 pigs per pen with 2 pens sharing a common feeder as the experimental unit).
[b]Total number of injection treatments administered per pen for the trial (@ 42 pigs per pen)

EFFECTS OF INCREASING CRYSTALLINE LYSINE AND DIETARY FAT ON FINISHING PIG GROWTH PERFORMANCE[1]

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Summary

A total of 1,024 barrows (each initially 157 lb, PIC L337 x C22) were used in a 28-d study to evaluate the effects of increased crystalline amino acids (none versus 4.5 lb/ton of L-lysine HCl plus L-threonine to maintain the proper ratio relative to lysine) and added dietary fat (none, 3 or 6% choice white grease) on finishing pig growth performance. All experimental diets were formulated with a constant true ileal digestible lysine:ME ratio based on NRC, (1998) ingredient values for ME. A minimum true ileal digestible threonine:lysine ratio of 68% and a minimum true ileal digestible methionine + cystine:lysine ratio of 55% were used in diet formulation. There was no synthetic amino acid by added fat interactions. Increasing added fat increased (linear, $P<0.01$) ADG and improved F/G. Replacing soybean meal with crystalline amino acids had no affect on growth performance. This indicates that the increased amounts of L-lysine HCl and added L-threonine were used as efficiently as amino acids provided from soybean meal. Neither adding fat nor crystalline lysine affected feed cost/lb of gain using current ingredient prices. However, margin over feed cost (profit) increased as added fat increased because of the increased pig weight due to improved ADG. In summary, these results confirm the improved ADG and F/G when adding fat to finishing pig diets. Furthermore, 4.5 lb/ton of L-lysine HCl and L-threonine can effectively replace soybean meal without negatively affecting growth performance of pigs from 157 to 217 lb.

(Key Words: Finishing Pigs, Growth Performance, Fat, Amino Acids)

Introduction

Adding fat to finishing pig diets has been shown to increase ADG and improve F/G with the growth response to added fat appearing to decrease after pigs weigh approximately 200 to 220 lb. Adding fat to swine diets typically increases diet cost, and in many cases also increases feed cost per lb of gain. However, if a production system works on a fixed time basis (i.e., only so many days before all pigs must be sold and room made for the next group of pigs), then increasing ADG by adding fat may actually increase profitability by selling more total pounds of pork over the same time period. Thus, even though fed cost per lb of gain increases with added fat, margin over feed costs (profit) also may increase.

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[2]Food Animal Health and Management Center.
[3]Ajinomoto Heartland LLC, Chicago, Illinois.

Use of synthetic amino acids in finishing diets has often been limited to 3 lb of L-lysine HCl per ton of feed because inclusion of higher levels reduces performance unless other amino acids are also added to the diet. The second limiting amino acid, L-threonine, was too expensive for routine addition before the opening of a new threonine production plant in the last year. With the new plant on line, practical application of higher levels of L-lysine HCl along with the L-threonine additions to replace soybean meal must be tested.

This experiment had two objectives: the first was to evaluate the effects of increasing added fat on finishing pig growth performance and economics. The second was to compare growth performance of pigs fed either none, or 4.5 lb/ton of L-lysine HCl and L-threonine as a replacement for soybean meal in the diet.

Procedures

A total of 1,024 barrows (each initially, 157 lb, PIC L337 x C22) was used in a 28-d study. Pigs were fed one of six experimental diets arranged in a 2 x 3 factorial (Table 1). Main effects included crystalline amino acid addition (none vs 4.5 lb/ton of L-lysine HCl plus L-threonine to maintain the proper ratio relative to lysine) and added dietary fat (none, 3 or 6% choice white grease). All experimental diets were formulated with a constant true ileal digestible lysine:ME ratio based on NRC, (1998) ingredient values for ME. A minimum true ileal digestible threonine:lysine ratio of 68% and a minimum true ileal digestible methionine + cystine:lysine ratio of 55% were used in diet formulation. There were 24 or 25 pigs per pen and seven pens (observations) per treatment. Pens of pigs and feeders were weighed at the start of the study and on days14 and 28 to calculate ADG, ADFI, and F/G.

Data were analyzed using the PROC MIXED procedures of SAS as a randomized complete block design with pen as the experimental unit. Main effects of added L-lysine HCl, added fat, and their interactions were evaluated. Linear and quadratic effects of increasing dietary fat were also determined.

Results and Discussion

There was no added synthetic amino acid by added fat interaction observed ($P>0.10$; Table 2 and 3). Increasing added fat increased (linear, $P<0.01$) ADG and improved F/G. Increasing added fat also increased (linear, $P<0.01$) average pig weight at the end of the 28-d study. Increasing added crystalline amino acids (none vs 4.5 lb/ton of L-lysine HCl plus other crystalline amino acids to maintain the proper ratio relative to lysine) had no affect on growth performance, suggesting that the increased use of L-lysine HCl with added L-threonine could be used as efficiently as amino acids provided from soybean meal. It is important to point out that minimum ratios of true ileal digestible threonine: lysine ratio (68%) was relatively high compared with other threonine requirement estimates but was slightly below the threonine: lysine ratio of the diets containing no added L-lysine HCl. Neither adding fat nor crystalline lysine affected feed cost/lb of gain using current ingredient prices. However, margin over feed cost (profit) increased as added fat increased because of the increased pig weight due to improved ADG.

In summary, these results confirm the improved ADG and F/G when adding fat to finishing pig diets (157 to 217 lb). In production systems that operate on a fixed time basis, the increased ADG can result in greater profitability as more pounds of pork can be sold within the same amount of time. Furthermore, 4.5 lb/ton of L-lysine HCl and L-threonine can effectively replace soybean meal without negatively affecting pig growth performance. Depending on ingredient prices, this substitution may lower diet cost and reduce nitrogen excretion in swine waste.

Table 1. Composition of Experimental Diets

	Added L-lysine HCl, lb/ton					
	0			4.5		
	Added Fat, %					
Ingredient, %	0	3	6	0	3	6
Corn	76.35	71.95	67.50	83.10	78.70	74.30
Soybean meal, 46.5%	21.15	22.55	24.00	14.05	15.50	16.90
Choice white grease	---	3.00	6.00	---	3.00	6.00
Monocalcium phosphate, 21% P	1.05	1.05	1.05	1.10	1.08	1.08
Limestone	0.93	0.93	0.93	0.93	0.93	0.93
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix with phytase	0.06	0.06	0.06	0.06	0.06	0.06
Trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10
L-Threonine	---	---	---	0.08	0.08	0.09
Lysine HCl	---	---	---	0.23	0.23	0.23
	100.00	100.00	100.00	100.00	100.00	100.00
True dig lysine:ME ratio	2.193	2.191	2.193	2.193	2.192	2.191
Total lysine, %	0.84	0.87	0.90	0.82	0.85	0.88
True ileal digestible amino acids,%						
Lysine	0.73	0.76	0.79	0.73	0.76	0.79
Isoleucine:lysine ratio	81	80	79	65	65	64
Leucine:lysine ratio	190	183	177	167	161	156
Methionine:lysine ratio	34	33	32	29	28	28
Met & Cys:lysine ratio	69	67	65	60	59	57
Threonine:lysine ratio	72	70	69	68	68	68
Tryptophan:lysine ratio	22	22	22	17	17	17
Valine:lysine ratio	93	91	90	77	76	75
ME, kcal/lb	1,509	1,570	1,632	1,505	1,567	1,628
Modified ME, kcal/lb	1,446	1,507	1,569	1,450	1,511	1,572
Protein, %	16.3	16.6	16.9	13.6	13.9	14.2
Ca, %	0.64	0.64	0.65	0.63	0.63	0.63
P, %	0.58	0.58	0.58	0.56	0.55	0.55
Available P, %	0.31	0.31	0.31	0.31	0.31	0.31

Table 2. Effects of Added Fat and Crystalline Lysine on Performance of 155-to 215-lb Barrows Raised in a Commercial Environment[a,b]

	Added L-lysine HCl, lb / ton												
	0			4.5					Probability (P>)				
	Added Fat, %											Fat	Lysine
Item	0	3	6	0	3	6	SED	SED	Lysine	Fat	Linear	Quadratic	x fat
Initial wt, lb	156.7	157.8	156.9	157.0	158.8	157.6	1.19	0.85	0.34	0.22	0.67	0.09	0.91
ADG, lb	2.06	2.11	2.14	1.92	2.12	2.16	0.06	0.04	0.30	0.002	0.001	0.24	0.15
ADFI, lb	6.30	6.20	6.05	6.11	6.19	6.14	0.09	0.06	0.50	0.19	0.10	0.46	0.12
F/G	3.05	2.95	2.83	3.18	2.91	2.85	0.08	0.05	0.41	0.001	0.001	0.32	0.35
Final wt, lb[c]	215.3	216.7	217.5	211.4	216.9	218.0	1.75	1.24	0.29	0.003	0.001	0.26	0.15
Feed cost/lb of gain, $[d]	0.184	0.186	0.187	0.189	0.182	0.186	0.005	0.003	0.98	0.66	0.86	0.38	0.40
IOMFC[e], $	11.34	11.53	11.58	10.32	11.78	11.74	0.58	0.42	0.55	0.09	0.06	0.26	0.25

[a]A total of 1,024 barrows (PIC L337 x C22) in 42 pens was used in a 2 (levels of added crystalline lysine) x 3 (levels of added fat) factorial design to evaluate the effects of increasing added fat and crystalline lysine.
[b]Threonine:lysine ratios were held to a minimum of 68%.
[c]Calculated end weight used initial weight as a covariate.
[d].Commodity prices of $ 2.40/bu corn, $ 180/ton SBM, $0.12/lb CWG, $ 0.76/lb lys; $1.20/lb thr.
[e]IOMFC, Income over marginal feed costs, = (Live price ($38CWT) × (calc wt 28 - wt 0)) - (adg × 28 days × feed cost/lb of gain).

Table 3. Main Effects of Added Fat and Crystalline Lysine on Performance of 155- to 215-lb Barrows Raised in a Commercial Environment[a,b]

	Main Effects							Probability (P>)				
	L-Lysine HCl, lb/ton			Added fat, %						Fat		Lysine
Item	0	4.5	SED	0	3	6	SED	Lysine	Fat	Linear	Quadratic	x fat
Initial wt, lb	157.1	157.8	0.69	156.9	158.3	157.2	0.85	0.34	0.22	0.67	0.09	0.91
ADG, lb	2.11	2.07	0.04	1.99	2.12	2.15	0.04	0.30	0.002	0.001	0.24	0.15
ADFI, lb	6.18	6.15	0.05	6.21	6.19	6.09	0.06	0.50	0.19	0.10	0.46	0.12
F/G	2.94	2.98	0.04	3.12	2.93	2.84	0.05	0.41	0.001	0.001	0.32	0.35
Final wt, lb[c]	216.5	215.4	1.01	213.4	216.8	217.71	1.24	0.29	0.003	0.001	0.26	0.15
Feed cost/lb of gain, $[d]	0.186	0.186	0.003	0.186	0.184	0.187	0.003	0.98	0.66	0.86	0.38	0.40
IOMFC[e], $	11.48	11.28	0.34	10.83	11.66	11.66	0.42	0.55	0.09	0.06	0.26	0.25

[a]A total of 1,024 barrows (PIC L337 x C22) in 42 pens was used in a 2 (levels of added crystalline lysine) x 3 (levels of added fat) factorial design to evaluate the effects of increasing added fat and crystalline lysine.
[b]Threonine:lysine ratios were held to a minimum of 68%.
[c]Calculated end weight used initial weight as a covariate.
[d]Commodity prices of $ 2.40/bu corn, $ 180/ton SBM, $0.12/lb CWG, $ 0.76/lb lys; $1.20/lb thr.
[e]IOMFC, Income over marginal feed costs, = (Live price ($38CWT) × (calc wt 28 - wt 0)) - (adg × 28 days × feed cost/lb of gain).

THE OPTIMAL TRUE ILEAL DIGESTIBLE LYSINE AND THREONINE REQUIREMENT FOR NURSERY PIGS BETWEEN 25 AND 55 LB[1]

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Summary

A total of 360 pigs (initially 22.2 lb and 31 d of age) was used in a 21-d growth assay. This trial was conducted as a combination of two separate trials in order to simultaneously examine both the true ileal digestible lysine and true ileal digestible threonine requirement and determine the appropriate threonine:lysine ratio. The first part of the trial consisted of five treatments with increasing dietary lysine (1.0. 1.1, 1.2, 1.3 and 1.4% true digestible lysine). The second part consisted of five treatments with increasing dietary threonine (0.66, 0.72, 0.78, 0.84 and 0.91% true ileal digestible threonine). The highest level of both lysine and threonine (1.4% and 0.91% respectively) served as a positive control, and this diet was combined as one treatment to give a total of nine treatments. Average daily gain increased to 1.3% true ileal digestible lysine, and then plateaued, while ADG increased to 0.78% true ileal digestible threonine, suggesting a threonine:lysine ratio of 60% for ADG. Increasing dietary lysine improved F/G linearly through 1.4% true ileal digestible lysine, while F/G improved up to a level of 0.84% true ileal digestible threonine. Using a level of 1.4% true ileal digestible lysine, a threonine:lysine ratio of approximately 60% is implicated for F/G.

Amino acid and plasma urea N values were measured on d 10 of the trial. Plasma lysine concentrations were maintained steadily as the true ileal digestible lysine level increased, with a slight increase in plasma lysine concentration observed as the true ileal digestible lysine level increased from 1.3% to 1.4%. A linear increase (P<.0001) in plasma threonine concentration was observed as true ileal digestible threonine increased from 0.66% to 0.91%. Plasma urea N decreased linearly (P<0.0003) with increasing true ileal digestible lysine. As true ileal digestible threonine increased, there was no difference seen in plasma urea N concentration. Following analysis of the data, a true ileal digestible threonine to lysine ratio of 60% is suggested. A second study is in progress where the higher true digestible lysine level of 1.5% is used to verify trial results.

(Key Words: Threonine, Lysine, Nursery Pigs)

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[1]The authors would like to thank Ajinomoto Heartland LLC, Chicago, Illinois, for partial funding of this project.

[2]Food Animal Health and Management Center

[3]Ajinomoto Heartland LLC, Chicago, Illinois.

Introduction

The current National Research Council (NRC; 1998) suggests a true ileal digestible threonine:lysine ratio of 62% for a 22- to 55-lb pig. This recommendation is derived from many trials that investigated the optimal threonine:lysine ratio by titrating different threonine levels in diets containing a predetermined lysine level. There are problems with this approach to determine a ratio, as a certain lysine level is chosen without knowledge of the actual lysine requirement for the specific group of pigs used in the various studies. We cannot be certain that the lysine level used initially is adequate for the pigs. The objective of this experiment was to determine the optimal ratio of threonine to lysine in diets to maximize growth performance of nursery pigs. To achieve our objective, two experiments were run simultaneously. One trial was conducted to determine the lysine requirement, and the second to determine the threonine requirement. By examining results of both studies, we are able to determine a threonine:lysine ratio.

Procedures

A total of 360 pigs (initially 22.2 lb and 31 d of age) was used in a 21-d growth assay. Pigs were weaned at an average age of 18 d and fed a common diet for 13 d before the experiment. Pigs were housed in an environmentally controlled nursery. Temperature was maintained at 87°F for the first week and reduced by 2°F each week to maintain pig comfort. Each pen (4-ft^2 with slatted metal flooring) contained a stainless steel self-feeder and one nipple waterer to allow ad libitum consumption of feed and water.

Diets were corn-soybean meal based (Table 1). The positive control diet was formulated with the highest lysine (1.4%) and threonine (.91%) level. In formulating the remaining diets, either L-lysine HCl or L-threonine was replaced with cornstarch. L-lysine HCl addition decreased to provide 1.3, 1.2, 1.1 and 1.0% true ileal digestible lysine. The diets for the threonine trial were set at 1.4% lysine, while crystalline L-threonine decreased to obtain 0.84, 0.78, 0.72, and 0.66% true ileal digestible threonine. Diets were fed in meal form.

Table 1. Composition of Diets (As-fed Basis)

Ingredient, %	Control Diet
Corn	61.94
Soybean meal, 46.5% CP	31.65
Soy oil	1.50
Monocalcium phosphate, 21% P	1.55
Limestone	0.95
Salt	0.35
Vitamin premix	0.25
Trace mineral premix	0.15
Antibiotic	0.50
L-Isoleucine	0.02
L-Valine	0.08
L-Tryptophan	0.03
L-Threonine	0.25
L-Lysine HCl	0.53
DL-Methionine	0.25
Cornstarch[a]	---
Total	100.0
True ileal digestible lysine, %	1.40
True ileal digestible threonine, %	0.91
Isoleucine:lysine ratio, %	55
Leucine:lysine ratio, %	114
Methionine:lysine ratio, %	38
Met & Cys:lysine ratio, %	60
Threonine:lysine ratio, %	65
Tryptophan:lysine ratio, %	17
Valine:lysine ratio, %	65
ME, kcal/lb	1,521
Protein, %	20.0
Ca, %	0.77
P, %	0.72
Available P, %	0.40
TID lysine:calorie ratio, g/mcal	4.18

[a]Cornstarch replaced L-lysine (1.0, 1.1, 1.2, 1.3, 1.4%) or L-threonine (0.66, 0.72, 0.78, 0.84, 0.91%) in the control diet to form the dietary treatments.

Experimental diets were fed for 21 d. Pigs were weighed, and feed disappearance measured on d 7, 14, and 21 to determine the response criteria of ADG, ADFI, and F/G. Blood samples were obtained by venipuncture on d 10 from two randomly selected pigs in each pen following a 3-hour period of feed deprivation. Plasma urea nitrogen (PUN) concentration was determined on each sample. Plasma from pigs in the same pen was pooled for amino acid analysis.

Data were analyzed as a randomized complete block design using the PROC MIXED procedure of SAS with pen as the experimental unit. Linear and quadratic polynomial contrasts were performed to determine the effects of increasing dietary lysine and threonine.

Results and Discussion

Overall, there was a linear increase in ADG ($P<0.003$) as dietary lysine content increased from 1.0 to 1.4% true ileal digestible lysine (Table 2). Although the response to lysine was linear, there was very little increase in ADG as true ileal digestible lysine increased from 1.3 to 1.4%. Feed efficiency improved linearly ($P<0.0001$) as true ileal digestible lysine increased, indicating that we may not have reached the pigs' requirement for lysine. Plasma urea N, measured on d 10, decreased linearly ($P<0.0003$) with increasing true ileal digestible lysine, with only a slight decrease being observed between 1.3% and 1.4% true ileal digestible lysine (Table 4). Plasma lysine concentrations were not affected by increasing true ileal digestible lysine, but numerically increased as true ileal digestible lysine increased from 1.3 to 1.4%. In the lysine trial, plasma threonine, phenylalanine, and valine concentrations continued to fall linearly up to 1.4% true ileal digestible lysine ($P<0.01$).

As dietary threonine increased, there was a quadratic ($P<0.05$) increase in ADG (Table 3). Average daily gain increased to 0.78% true ileal digestible threonine and plateaus thereafter. A linear improvement in F/G ($P<0.001$) was observed as true ileal digestible threonine increased from 0.66% to 0.84%. Plasma urea N concentration was maintained as true ileal digestible threonine increased from 0.66% to 0.91%. Plasma threonine concentration increased linearly ($P<0.001$) with increasing dietary threonine. Plasma lysine concentration decreased quadratically ($P<0.004$), while plasma methionine concentration increased quadratically ($P<0.03$) for pigs fed levels of true ileal digestible threonine increasing from 0.66 to 0.91%.

Average daily gain increased with increasing dietary lysine up to a level of 1.3%, and up to 0.78% true ileal digestible threonine. Feed efficiency improved linearly as true ileal digestible lysine increased to 1.4%, while increasing dietary threonine improved F/G up to 0.84%. Thus, a ratio of 60% is implicated for both ADG and F/G. Typically, the requirement for F/G is higher than for ADG, which is also reflected in the blood analysis. In the current lysine trial, it appears from both the AA and PUN analysis, that our highest level of lysine (1.4% true ileal digestible) may not have reached the level required by these pigs for optimum performance. The results of our experiment suggest that the true ileal digestible threonine:lysine ratio for 22- to 55-lb pigs is approximately 60%.

The results of both experiments closely reflect results of other recent trials. A series of lysine experiments at Kansas State University and the University of Missouri indicates that the optimal lysine level for 25- to 55-lb pigs may be close to 1.32% true ileal digestible lysine or 1.46% total lysine. These requirements are substantially higher than the true ileal digestible lysine requirement of 1.1% suggested by NRC (1998). Similar to the higher lysine requirement, the true ileal digestible threonine requirement of 0.78 to 0.84% is considerably higher than the level of 0.63% suggested by NRC (1998). However, when compared on a

ratio basis, the 60% true ileal digestible threonine to lysine ratio as suggested by this trial is very similar to the 62% suggested by the NRC (1998). Because the lysine response was linear through the highest level fed, further research needs to be conducted to verify the optimum ratio of true ileal digestible threonine to lysine to maximize performance in nursery pigs. A future trial at Kansas State University is planned where the highest level of lysine used will be 1.5% true ileal digestible lysine, to verify current results.

Table 2. The Optimal True Ileal Digestible Lysine and Threonine Requirement for Nursery Pigs[a]

	Lysine, %					Threonine, %						Lysine		Threonine	
Item	1.0	1.1	1.2	1.3	1.4	0.66	0.72	0.78	0.84	0.91	SED	Linear	Quadratic	Linear	Quadratic
D 0 to 14															
ADG, lb	0.800	0.827	0.801	0.879	0.899	0.815^{f}	0.849^{cf}	0.919^{cd}	0.972^{c}	0.899^{ce}	0.056	0.053	0.556	0.025	0.126
ADFI, lb	1.143	1.159	1.098	1.185	1.138	1.120	1.153	1.178	1.203	1.138	0.068	0.906	0.898	0.532	0.226
F/G	1.462^{c}	1.422^{cde}	1.457^{cd}	1.384^{cdef}	1.311^{f}	1.431^{c}	1.398^{cd}	1.330^{d}	1.248^{e}	1.311^{de}	0.042	0.002	0.174	0.000	0.156
D 0 to 21[b]															
ADG, lb	1.015^{e}	1.048^{cde}	1.033^{e}	1.129^{cd}	1.134^{c}	1.029^{f}	1.099^{cdef}	1.163^{c}	1.152^{cd}	1.134^{cde}	0.051	0.003	0.656	0.014	0.048
ADFI, lb	1.489^{cd}	1.466^{cd}	1.417^{d}	1.521^{c}	1.466^{cd}	1.420^{d}	1.476^{cd}	1.524^{c}	1.500^{cd}	1.466^{cd}	0.065	0.940	0.530	0.333	0.074
F/G	1.480^{c}	1.415^{cde}	1.428^{cd}	1.372^{def}	1.315^{f}	1.428^{c}	1.375^{cd}	1.334^{d}	1.296^{e}	1.315^{de}	0.037	<.0001	0.598	0.001	0.142

[a]A total of 360 pigs (5 pigs/pen) with an initial average BW of 22.2 lb.

[b]Treatment diets were fed from d 0 to 21.

[cdef]Means in the same row with different superscripts differ (P<0.05).

Table 3. Effect of True Ileal Digestible Threonine:Lysine Ratio on Plasma Amino Acid Profile and PUN of the Nursery Pig[a]

												Probability (P<)			
	Lysine, %					Threonine, %						Lysine		Threonine	
Amino acid, µm/L	1.0	1.1	1.2	1.3	1.4	0.66	0.72	0.78	0.84	0.91	SED	Linear	Quadratic	Linear	Quadratic
Lysine	89	82	96	103	120	219	242	195	107	120	17.79	0.15	0.56	<.0001	0.004
Threonine	648	667	482	423	319	69	86	127	216	319	37.74	<.0001	0.40	0.001	0.32
Alanine	641	696	682	667	746	593	663	770	711	746	51.99	0.27	0.81	0.83	0.06
Histidine	62	50	62	42	40	43	39	44	31	40	8.74	0.06	0.72	0.36	0.65
Isoleucine	142	158	139	138	134	128	128	137	133	134	7.83	0.16	0.47	0.93	0.48
Leucine	195	215	206	203	185	175	174	195	186	185	11.98	0.40	0.12	0.87	0.24
Methionine	49	56	60	56	50	47	44	53	58	50	3.95	0.87	0.03	0.16	0.03
Phenylalanine	108	108	102	97	81	86	85	84	95	81	5.36	0.0003	0.13	0.32	0.34
Tryptophan	37	36	40	34	29	36	31	33	35	29	3.00	0.06	0.11	0.85	0.74
Tyrosine	103	108	106	100	93	90	94	98	112	93	9.65	0.37	0.45	0.39	0.14
Valine	312	329	293	269	211	245	233	220	221	211	15.24	<.0001	0.02	0.67	0.37
PUN, mg/dL	40.51	41.33	35.38	29.49	27.58	33.05	26.86	23.46	30.89	27.58	3.07	0.0003	0.64	0.11	0.31

[a]Values are means of 8 replications (pens) of individual samples from two pigs per pen for plasma urea nitrogen (PUN) concentration and pooled samples from two pigs per pen plasma amino acid concentrations. Blood samples were collected on d 10, following 3 h feed withdrawal.

THE OPTIMAL TRUE ILEAL DIGESTIBLE LYSINE REQUIREMENT FOR 22 TO 45 LB PIGS[1]

N.A. Lenehan, S.S. Dritz[2], M.D. Tokach, R.D. Goodband, J.L. Nelssen, J.M. DeRouchey, and J.L. Usry[3]

Summary

A total of 1,440 pigs (initially 22.5 lb and 21 d after weaning) was used in a 21-d growth assay to determine the optimal lysine level to maximize growth performance of 22- to 45-lb pigs. Pigs were fed one of five dietary treatments with increasing dietary lysine (1.1, 1.2, 1.3, 1.4 and 1.5% true digestible lysine). All diets had the same soybean meal level with crystalline amino acids added to achieve the increasing lysine levels while maintaining a minimum ratio of all other amino acids to lysine. Average daily gain and feed efficiency improved linearly ($P<0.01$) with increasing dietary lysine. Although the response to lysine was linear ($P<0.01$), it would appear that pigs weighing between 22 and 45 lb require approximately 1.4% true digestible lysine (1.54% total lysine) to maximize growth performance.

(Key Words: Pigs, Lysine, Growth)

Introduction

Since dietary lysine level has a major impact on growth performance, the prediction of the optimal requirement is important.

The NRC (1998) recommendations of 1.01% true ileal digestible lysine or 1.15% total lysine for the 22- to 45-lb pig is lower than current levels fed in commercial production. An accurate estimate of the lysine requirement also is essential for accurate estimation of the optimal ratio of other amino acids relative to lysine. Therefore, the objective of this experiment was to determine the optimal lysine level in diets to maximize growth performance of late nursery pigs.

Procedures

Pigs were blocked by gender, allotted, and placed on their respective experimental diets on d 21 after weaning. There were 60 pens in total and 24 pigs/pen. Two pens shared the same feeder, with feeder as the experimental unit. Thus, there were 48 pigs per experimental unit and 6 replications per treatment. Pigs were housed in an environmentally controlled nursery. Temperature was set at 74°F on d 21, and reduced to 68°F by d 32 to maintain pig comfort. Each pen (5 × 10 ft with slatted plastic flooring) contained a stainless steel self-feeder and one cup waterer to allow *ad libitum* consumption of feed and water. Experimental diets were fed for 21 d. Pigs were weighed and feed disappearance measured on d 28, 35,

[1]The authors would like to thank Ajinomoto Heartland LLC, Chicago, Illinois, for partial funding of this project.
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and 42 to determine the response criteria of ADG, ADFI, and F/G.

Diets were corn-soybean meal based (Table 1). Synthetic amino acids were used to achieve higher lysine levels while avoiding the addition of excessive quantities of soybean meal. L-lysine HCl addition was increased to provide 1.1, 1.2, 1.3, 1.4, and 1.5% true ileal digestible lysine. Diets were fed in meal form.

Data were analyzed as a randomized complete block design using the PROC MIXED procedure of SAS with 2 pens used as the experimental unit. Linear and quadratic polynomial contrasts were performed to determine the effects of increasing dietary lysine.

Results and Discussion

Overall, there was a linear increase in ADG ($P<0.01$) as the lysine content increased from 1.1 to 1.5% true ileal digestible lysine (Table 2). Feed efficiency also improved linearly ($P<0.001$) as the level of true ileal digestible lysine increased. Although statistical analysis suggests an increase in both ADG and F/G as the level of true ileal digestible lysine increases to 1.5%, the further improvements in ADG and F/G beyond that in pigs fed a diet containing 1.4% true ileal digestible lysine was minimal.

The results of this experiment suggest that the lysine requirement of these pigs is significantly higher than the level recommended by the NRC (1998). Research previously conducted at the University of Missouri indicates a true ileal digestible lysine requirement of approximately 1.32% for pigs in this growth phase. Data from the current trial indicate a requirement of 1.4% true ileal digestible lysine. Further research needs to be conducted in order to verify that the optimum lysine level for a 22- to 45-lb pig is approximately 1.4% true ileal digestible lysine (1.54% total lysine).

Table 1. Diet Composition (As-fed Basis)

	True Digestible Lysine, %				
Ingredient, %	1.1	1.2	1.3	1.4	1.5
Corn	59.52	59.47	59.35	58.7	58.30
Soybean meal, 46.5%	33.85	33.85	33.85	33.85	33.85
Choice white grease	3.00	3.00	3.00	3.00	3.00
Dicalcium phosphate, 18.5% P	1.40	1.40	1.40	1.40	1.40
Limestone	0.75	0.75	0.75	0.75	0.75
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin/trace mineral premix	0.30	0.30	0.30	0.30	0.30
Medication[a]	0.70	0.70	0.70	0.70	0.70
L-threonine	---	0.07	0.13	0.20	0.26
L-tryptophan	---	---	---	0.01	0.03
L-valine	---	---	---	0.04	0.11
L-isoleucine	---	---	---	---	0.06
Lysine HCl	0.08	---	---	0.46	0.59
DL-methionine	0.05	0.11	0.17	0.24	0.30
Total	100.0	100.0	100.0	100.0	100.0
Total lysine, %	1.24	1.34	1.44	1.54	1.64
Isoleucine:lysine ratio, %	73	67	62	58.3	56.8
Leucine:lysine ratio, %	148	137	127	118	111
Methionine:lysine ratio, %	30	33	35	36	38
Met & Cys:lysine ratio, %	60	60	60	60	60
Threonine:lysine ratio, %	64.6	64.6	64.5	64.4	64.4
Tryptophan:lysine ratio, %	21	19	18	17.4	17.4
Valine:lysine ratio, %	81	75	69	67	67
ME, kcal/lb	1,551	1,547	1,543	1,538	1,532
Protein, %	20.8	20.8	20.8	20.8	20.9
Ca, %	0.71	0.71	0.71	0.71	0.71
P, %	0.66	0.66	0.66	0.66	0.66
Available P, %	0.34	0.34	0.34	0.34	0.34
Lysine:calorie ratio, g/mcal	3.62	3.92	4.22	4.53	4.84

[a]Provided 140g/ton neomycin and 140g/ton oxytetracycline.

Table 2. Influence of Dietary Lysine Level on 22- to 45-lb Pig Performance[a]

	True Digestible Lysine, %						Probability P<	
Item	1.1	1.2	1.3	1.4	1.5	SEM	Linear	Quadratic
D 21 to 42								
ADG, lb	1.03	1.05	1.09	1.14	1.13	0.03	0.01	0.76
ADF, lb	1.56	1.54	1.55	1.56	1.56	0.04	0.71	0.78
F/G	1.51	1.47	1.42	1.37	1.38	0.02	0.001	0.20
Avg weight, lb								
d 21	22.6	22.5	22.6	22.6	22.8	0.4	0.84	0.72
d 42	44.3	44.5	45.5	46.5	46.6	0.8	0.01	0.93

[a]A total of 1,440 pigs (24 pigs per pen) with an initial average BW of 22.6 lb.

THE INFLUENCE OF DIETARY FAT LEVEL AND CRYSTALLINE AMINO ACID ADDITIONS ON GROWTH PERFORMANCE OF 25- TO 50-LB PIGS[1]

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Summary

To determine the effects of increasing added fat on pig growth performance 1,440 pigs (each initially 26 lb) were used in a 21 d growth trial. Pigs were fed diets containing none, 1.5, 3.0, 4.5, and 6.0% choice white grease. Increasing added fat reduced (linear, P<0.05) ADFI and improved F/G. Although ADG was not significantly affected by fat level, increasing added fat from 0 to 1.5% or greater resulted in a 1-lb increase in total weight gain over the entire trial. The greatest improvement in feed efficiency was also observed with the addition of the first 1.5% fat; however, further increases in dietary fat continued to linearly reduce ADFI and improve F/G. These results would suggest that from 25 to 50 lb, 1.5 to 3.0% added fat optimized pig growth performance. Based on the results of Experiment 1, we conducted Experiment 2 to confirm the optimum level of added fat in combination with increased use of crystalline amino acids (3 vs 6 lb/ton L-lysine + other amino acids) to meet the pig's lysine requirements. In Experiment 2, 1,152 pigs (each initially 21 lb) were fed one of four dietary treatments arranged in a 2 x 2 factorial. Main effects included added fat (3 or 6%) and crystalline amino acid amounts (3 vs 6 lb/ton L-lysine HCl with other amino acids added to maintain proper amino acid to lysine ratios). No differences were observed in growth performance, but based on current ingredient prices, reducing the amount of soybean meal by the use of higher levels of crystalline amino acids increased margin over feed cost. In conclusion, these data indicate that 3% added fat will optimize growth performance and margin over feed costs, and that the use of greater amounts of crystalline amino acids (up to 6 lb/ton L-lysine with added L-threonine and DL methionine) are efficiently used by the pig and will also help further increase margin over feed costs.

(Key Words, Pigs, Growth, Synthetic Amino Acids, Fat)

Introduction

Previous studies have demonstrated the positive response to adding increasing amounts of fat to growing and finishing pig diets. However, there has been some concern that nursery pigs do not show the same response as finishing pigs to high levels of fat. In diets fed immediately after weaning, high levels of fat are used only to aid in the pelleting process to prevent burning and scorching

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of the milk products. In the later nursery stages, protein deposition may be limited by energy intake. High levels of fat in the diet are used to improve lean gain. In addition to the energy density of the diet, we have also recently observed an increase in dietary lysine requirements of pigs fed from 13 to 45 lb. In these experiments, diets contained greater amounts crystalline amino acids than used in the past (up to 6 lb/ton with added L-threonine and DL methionine). The purpose of Experiment 1 was to determine the ideal level of fat to add to diets for 25- to 50-lb pigs for optimal performance and economics. Experiment 2 was to confirm the results of Experiment 1 in conjunction with increased dietary lysine concentrations observed in previous studies.

Procedures

A total of 1,440 pigs (each initially 26 lb) was used in a 21-d growth trial to determine the effects of increasing added fat on pig growth performance. Pigs were housed in a commercial nursery in southern Minnesota and fed diets containing none, 1.5, 3.0, 4.5, and 6.0% choice white grease (Table 1). Each diet was formulated using the same true ileal digestible lysine:Kcal ME ratio. Experimental diets met or exceeded the nutrient requirement estimates suggested by the National Research Council (NRC; 1998). There were 60 pens (30 of barrows and 30 of gilts) with 24 pigs per pen. All pigs were phase fed the same SEW, Transition, and Phase II diets from weaning to d 21, when they were weighed and randomly assigned to their experimental diets. Pigs were weighed and feed disappearance determined at the start of the study and on d 7, 14, and 21 to calculate ADG, ADFI, and F/G.

In Experiment 2, pigs were housed in the same nursery facility as in Experiment 1. However, there were only 48 pens used in the study, and each contained 24 pigs. The study was initiated 17 days after weaning when the pigs averaged 21.8 lb, and lasted 21 days. Pens of pigs were randomly allotted to one of four dietary treatments arranged in a 2 x 2 factorial (Table 2). Main effects included added fat (3 or 6%) and the amount of crystalline amino acids (3 or 6 lb/ton of L-lysine HCl with other amino acids added to maintain minimum ratios relative to lysine). Diets were formulated to contain either 1.50 or 1.56% total lysine for the 3 and 6% added fat treatments, respectively, thus maintaining a constant calorie:lysine ratio. In the diets containing 6 lb/ton L-lysine, approximately 90 lb of soybean meal was replaced by crystalline lysine and other amino acids compared with diets containing only 3 lb/ton of L-lysine.

Data in both trials were analyzed using the PROC MIXED procedures of SAS as a randomized complete block design, with two pens consuming feed from a single feeder as the experimental unit. Linear and quadratic effects of increasing dietary fat were evaluated in Experiment 1. Experiment 2 was as a 2 x 2 factorial with analysis of main effects and their interactions.

Results and Discussion

Increasing added fat in diets from 26 to 53 lb reduced (linear, $P<0.01$) ADFI and improved F/G. Although ADG was not significantly influenced by added fat, increasing the fat level from 0 to 1.5% or above resulted in approximately a 1-lb increase in total weight gain over the entire trial. The greatest improvement in feed efficiency was also due to the addition of the first 1.5% fat, although continued reductions in ADFI and improvements in F/G were observed.

As expected, adding fat increased diet cost approximately $4.00 for every 1.5% addition. Feed cost per pound of gain was not greatly influenced by the addition of fat; however, it was numerically increased as the fat level was increased above 1.5% of the diet. Previous recommendations have been to add 5 to 6% more fat to diets for pigs from 25 to 50 lb. This has been based on extrapolating results

observed with growing-finishing pigs that have observed linear responses in ADG and F/G up to 6% added fat. However, because in the present study there was no change in weight gain, it would appear that the amount of added fat could be lowered from 6% to at least 3%.

Based on results of this and previous experiments, we have recommended increasing lysine levels, lowered the fat level, and implemented use of more synthetic lysine and threonine. Therefore, the objective of Experiment 2 was to confirm the results of these changes in a single trial.

In Experiment 2, increasing added fat from 3 to 6% had no effect ($P>0.10$) on ADG, ADFI, or F/G. This was consistent with results of Experiment 1. Furthermore, pig growth performance was similar, whether the diets contained either 3 or 6 lb/ton of L-lysine HCl with other crystalline amino acids. This indicates that growing pigs efficiently utilized greater amounts of L-lysine HCl (6 lb/ton) as long as other crystalline amino acids were used to maintain proper ratios relative to lysine.

As expected, adding 6% fat increased diet cost compared to diets containing 3% added fat. Furthermore, based on current ingredient prices, the use of 6 lb/ton of L-lysine with additions of L-threonine and DL methionine increased diet cost relative to adding only 3 lb/ton of L-lysine. However, the relatively small changes in F/G resulted in very similar feed cost per lb of gain. This, combined with numerical increases in ADG of pigs fed the high crystalline amino acid-containing diets, actually resulted in slightly greater profitability than those diets containing 6% fat or more soybean meal. While the differences in pig growth performance were not significant, and ingredient prices may be variable, our data suggest that decreasing fat from 6 to 3% and using greater amounts of L-lysine HCl (6 lb/ton), with additions of L-threonine and DL methionine will not hurt pig growth performance.

Table 1. Experimental Diets, Experiment 1 (As-fed Basis)[a]

	Added Fat, %				
Ingredient, %	0	1.5	3	4.5	6
Corn	58.15	56.55	54.95	53.40	51.80
Soybean meal, 46.5% CP	37.90	37.90	37.90	37.90	37.90
Choice white grease	0.00	1.50	3.00	4.50	6.00
Dicalcium phosphate, 18.5% P	1.40	1.40	1.40	1.40	1.40
Limestone	0.75	0.75	0.75	0.75	0.75
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin & trace mineral premix	0.30	0.30	0.30	0.30	0.30
Medication	0.70	0.70	0.70	0.70	0.70
L-Threonine	0.09	0.11	0.13	0.15	0.17
L-Lysine HCl	0.24	0.28	0.32	0.35	0.39
DL-Methionine	0.15	0.17	0.19	0.21	0.24
Total	100.0	100.0	100.0	100.0	100.0
Calculated analysis					
Total lysine, %	1.48	1.51	1.54	1.56	1.59
Isoleucine:lysine ratio, %	66	65	63	62	61
Leucine:lysine ratio, %	132	129	126	123	120
Methionine:lysine ratio, %	34	34	35	36	36
Met & Cys:lysine ratio, %	60	60	60	60	60
Threonine:lysine ratio, %	65	64	64	64	64
Tryptophan:lysine ratio, %	19	19	18	18	17
Valine:lysine ratio, %	73	72	70	68	67
ME, kcal/lb	1,483	1,512	1,542	1,572	1,601
Crude protein, %	22.6	22.4	22.3	22.2	22.0
Ca, %	0.73	0.72	0.72	0.72	0.72
P, %	0.68	0.68	0.67	0.67	0.67
Available P %	0.45	0.45	0.45	0.45	0.44
Lysine:calorie ratio, g/mcal	4.54	4.53	4.52	4.51	4.50
Avail P:calorie ratio g/mcal	1.37	1.34	1.31	1.28	1.26
True Digestible amino acids					
Lysine	1.34	1.36	1.39	1.42	1.44
Isoleucine:lysine ratio, %	65	64	62	61	59
Leucine:lysine ratio, %	132	128	125	122	118
Methionine:lysine ratio, %	35	36	36	37	38
Met & Cys:lysine ratio, %	60	60	60	60	60
Threonine:lysine ratio, %	62.6	62.5	62.5	62.5	62.4
Tryptophan:lysine ratio, %	19	18	18	18	17
Valine:lysine ratio, %	71	70	68	66	65
True dig lys:cal ratio	4.09	4.09	4.09	4.09	4.09

[a]Diets were fed from d 21 to 42 after weaning and nutrient profiles were calculated using ingredient values from NRC, (1998).

Table 2. Experimental Diets, Experiment 1 (As-fed Basis)[a]

	3% Fat		6% Fat	
Ingredient, %	High AA[b]	Low AA	High AA	Low AA
Corn	56.04	51.97	50.62	46.52
Soybean meal, 48% CP	37.04	41.37	39.44	43.81
Choice white grease	3.00	3.00	6.00	6.00
Dicalcium phosphate, 18.5% P	1.35	1.35	1.35	1.35
Limestone	0.70	0.70	0.70	0.70
Salt	0.35	0.35	0.35	0.35
Vitamin & trace mineral premix	0.30	0.30	0.30	0.30
Medication	0.70	0.70	0.70	0.70
L-Lysine HCl	0.30	0.15	0.30	0.15
L-Threonine	0.13	0.05	0.13	0.05
DL-Methionine	0.10	0.06	0.12	0.08
Total	100.0	100.0	100.0	100.0
Total lysine, %	1.50	1.50	1.56	1.56
ME, kcal/lb	1,545	1,549	1,606	1,610
Calcium, %	0.69	0.71	0.70	0.71
Phosphorus, %	0.66	0.68	0.66	0.68
Available phosphorus, %	0.33	0.34	0.33	0.34
Available phosphorus equiv, %	0.41	0.41	0.41	0.42
Lysine:calorie ratio, g/mcal	4.40	4.40	4.40	4.40
True Ileal digestible amino acids				
Lysine	1.36	1.35	1.41	1.40
Isoleucine:Lysine ratio, %	61	67	61	67
Leucine:lysine ratio, %	127	135	124	132
Methionine:lysine ratio, %	30	29	31	29
Met & Cys:lysine ratio, %	55	55	55	55
Threonine:lysine ratio, %	63	62	62	62
Tryptophan:lysine ratio, %	18	20	18	20
Valine:Lysine ratio, %	69	74	68	74

[a]Diets were fed from d 21 to 42 after weaning, and nutrient profiles were calculated using ingredient values from NRC, (1998).
[b]Low and High designate the amounts of crystalline amino acids added to each diet.

Table 3. Effect of Fat Level on Growth Performance and Diet Economics from 26 to 53 lb

	Added fat, %						P values		
Item	0	1.5	3.0	4.5	6.0	SEM	Fat	Linear	Quadratic
ADG, lb	1.24	1.29	1.29	1.28	1.28	0.02	0.56	0.27	0.27
ADFI, lb	1.96	1.93	1.89	1.84	1.81	0.024	0.001	0.001	0.92
F/G	1.57	1.49	1.47	1.43	1.41	0.014	0.001	0.001	0.11
Diet cost, $/ton	150.00	154.40	158.80	163.20	167.60				
Feed cost/lb of gain, $	$0.117	$0.115	$0.116	$0.116	$0.117				
Total wt gain, lb	26.1	27.0	27.0	26.9	26.9				
Feed cost for 27 lb of gain, $/pig	$3.17	$3.11	$3.13	$3.14	$3.16				

Table 4. Effects of Added Fat Level and Crystalline Amino Acid Additions on Growth Performance and Feed Costs in 21- to 45-lb Pigs[a]

	3% Fat		6% Fat		
Ingredient, %	High AA[b]	Low AA	High AA	Low AA	SE
Initial wt, lb	21.83	21.85	21.85	21.87	0.31
ADG, lb	1.13	1.10	1.12	1.11	0.03
ADFI, lb	1.63	1.62	1.60	1.58	0.04
F/G	1.45	1.48	1.44	1.44	0.03
Final wt, lb	45.6	44.9	45.5	45.1	0.60
Diet cost, $/ton	158.10	156.17	167.69	165.79	
Total feed cost $/pig	2.71	2.65	2.81	2.75	
Feed cost, $/lb gain	0.114	0.115	0.119	0.118	
Margin over feed cost, $	6.80	6.57	6.65	6.54	
Difference, $[c]	0.25	0.03	0.11	-	

[a]Each value represents the mean of 6 observations, with 2 pens and a single fenceline feeder per observation. There were 24 pigs per pen.
[b]No differences (P>0.10) were observed among treatment means.
[c]Difference represents the change in margin over feed cost compared with pigs fed the least profitable dietary treatment.

EFFECTS OF DIET COMPLEXITY AND REPLACEMENT OF SOYBEAN MEAL ON GROWTH PERFORMANCE OF WEANLING PIGS

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Summary

A total of 192 pigs (avg initial BW of 13.9 lb and avg initial age of 21 d) was used to determine the effects of complex diet formulations (with plasma protein and whey) in nursery diets with wheat gluten used to replace soybean meal. Treatments were arranged as a 2 x 2 factorial, with main effects of diet complexity (no animal plasma and 10% dried whey vs 7% animal plasma and 20% dried whey) and soybean meal (25% vs none). For d 0 to 14, the complex diet formulations increased ADG while replacement of the soybean meal with wheat gluten decreased ADG ($P<0.001$). Efficiency of gain was improved by 7% when plasma and whey were increased in the formulations ($P<0.04$) but not affected by deletion of soybean meal ($P=0.15$ or greater). When all the pigs were changed to a common Phase 2 diet (with soybean meal and without plasma) for d 14 to 28, ADG and ADFI were less for those pigs fed the more complex formulations during the first 14 d of the experiment ($P<0.002$). Overall (d 0 to 28), pigs fed diets with soybean meal for d 0 to 14 had greater ADG and ADFI, and pigs fed the diets with plasma and 20% whey had better feed/gain ($P<0.007$). In conclusion, complex formulations (i.e., with 7% plasma and 20% whey) for d 0 to 14 improved growth performance regardless of the absence or presence of soybean meal, and using wheat gluten to rid the Phase 1 diets of soybean meal was of no benefit.

(Key Words: Nursery, Plasma, Whey, Soybean Meal)

Introduction

Research reports from Kansas State University indicate few (if any) problems with 20 to 30% soybean meal in Phase 1 nursery diets with complex formulations (e.g., with high inclusions of animal plasma, whey powder and fishmeal). Yet, anecdotal reports from Latin America, where milk products and animal plasma are too expensive or not available, suggest limiting inclusion of soybean meal to 10% or less in Phase 1 diets. Therefore we conducted an experiment to determine the effects of complex diet formulations on the response of weanling pigs to deletion of soybean meal in Phase 1 diets.

Procedures

A total of 192 pigs (avg initial BW of 13.9 lb and avg initial age of 21 d) were used in the 28-d growth assay. The pigs were sorted by sex, blocked by weight, and allotted to pens (six pigs per pen and eight pens per treatments). The pens were 3.5-ft × 5-ft with a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. For d 0 to 14, dietary treatments were arranged as a 2 x 2 factorial with main effect of diet complexity (no plasma and 10% dried whey vs 7% plasma and 20% dried whey) and inclusion of SBM (25% vs none). Fishmeal was increased in the simple diet formulations to replace the protein from plasma, and whey powder and wheat gluten were increased primarily in the formulations for the diets without soybean meal. All diets for d 0 to 14 had 1.8% lysine, 0.9% Ca, and 0.8% P (Table 1). For d 14 to 28, all pigs were given the same corn-soybean

meal based diet (Table 2) with 1.5% lysine, 0.8% Ca, and 0.7% P.

To begin the experiment and on d 14 and 28, the pigs and feeders were weighed to allow calculation of ADG, ADFI, and F/G. All data were analyzed as a randomized complete block design with a 2 × 2 factorial arrangement of treatments using the PROC MIXED procedure of SAS.

Table 2. Diet Composition for Day 14 to 28[a]

Ingredient	%
Corn	51.61
Soybean meal	26.75
Dried whey	10.00
Fishmeal	5.00
L-lysine HCl	0.29
D,L-methionine	0.12
L-threonine	0.11
L-tryptophan	0.00
Soybean oil	3.00
Dicalcium phosphate	0.79
Limestone	0.48
Salt	0.35
Vitamin premix	0.25
Mineral premix	0.15
Copper sulphate	0.09
Antibiotics[b]	1.00

[a]Formulated to 1.5% lysine, 0.8% Ca, and 0.7% P.
[b]Provided 50 g/ton carbadox.

Results and Discussion

For d 0 to 14 (Table 3), there were no interactions among complexity of diet formulation and removal of the soybean meal (P=0.15 or greater). However, the complex diet formulations (with 7% plasma and 20% dried whey) increased ADG by 14%, ADFI by 19% (P<0.001), and F/G by 7% (P<0.04). Replacing the soybean meal decreased ADG by 17% and ADFI by 22%. So, the diets with plasma protein and more whey powder increased growth performance, and replacing soybean meal was of no benefit, regardless of diet complexity.

For d 14 to 28, pigs previously fed the complex formulations (for d 0 to 14) had lower ADG (P<0.002) and ADFI (P<0.003) than pigs initially fed the simpler diet formulations. This response suggested that having to deal with the simple diets for d 0 to 14 better prepared the piglets for the transition to the simple Phase 2 formulation. Finally, there was an interaction for F/G among diet complexity and soybean meal inclusion (P<0.03) with replacement of the soybean meal having a negative effect when pigs were fed the simple diets in Phase 1 and a positive effect in pigs fed the more complex formulations in Phase 1.

Overall (d 0 to 28), F/G was 3% better (P<0.007) when pigs were fed the complex formulations for d 0 to 14. Also, there was 6% greater ADG and ADFI for pigs fed diets with soybean meal in Phase 1 (P<0.003). So, even though the pigs fed simpler diets for the first 14 d postweaning made the transition to the Phase 2 diets more readily, they never overcame their sharply lower performance for that first 14 d after weaning.

In conclusion, the more complex formulations improved growth performance for d 0 to 14 of the nursery phase. There was some difficulty with transition to the simple Phase 2 diet for pigs fed the more complex formulations in Phase 1, with lower ADG and ADFI, but that short lag in performance was outweighed by the better early growth for pigs given the more complex diet for d 0 to 14. Finally, we were not able to demonstrate a benefit when wheat gluten was used to replace soybean meal in Phase 1 diets.

Table 1. Diet Composition (d 0 to 14)[a]

	Simple Formulations		Complex Formulations	
Ingredient, %	25% soybean meal	0% soybean meal	25% soybean meal	0% soybean meal
Corn	47.02	45.65	34.17	40.95
Soybean meal	25.00	-	25.00	-
Dried whey	10.00	10.00	20.00	20.00
Spray-dried animal plasma	-	-	7.00	7.00
Wheat gluten	5.04	30.94	5.00	22.23
Fish meal	6.00	6.00	3.00	3.00
L-lysine HCL	0.61	1.15	0.11	0.77
DL-methionine	0.26	0.28	0.10	0.20
L-threonine	0.22	0.06	-	-
L-valine	0.15	0.14	-	0.04
L-tryptophan	0.04	0.05	-	0.01
Soybean oil	2.00	2.00	2.00	2.00
Dicalcium phosphate	1.10	0.99	0.75	0.87
Limestone	0.43	0.61	0.82	0.89
Salt	0.35	0.35	0.25	0.25
Vitamin premix	0.25	0.25	0.25	0.25
Mineral premix	0.15	0.15	0.15	0.15
Zinc oxide	0.39	0.39	0.40	0.39
Antibiotic[b]	1.00	1.00	1.00	1.00

[a]Diets were formulated to 1.8% lysine, 0.9% Ca, and 0.8% P.
[b]Provided 50 g/ton carbadox.

Table 3. Effect of Plasma and Soybean Meal Inclusion on Growth Performances of Nursery Pigs[a]

	Simple Formulations		Complex Formulations					
Item	25% soybean meal	0% soybean meal	25% soybean meal	0% soybean meal	SE	Simple vs complex	Soybean meal effect	Interaction effect
Phase 1 (d 0 to 14)								
ADG, lb	0.76	0.59	0.87	0.74	0.03	0.001	0.001	-[b]
ADFI, lb	0.77	0.66	0.88	0.75	0.02	0.001	0.001	-
F/G	1.06	1.15	1.03	1.04	0.03	0.04	-	-
Phase 2 (d 14 to 28)								
ADG, lb	1.28	1.32	1.20	1.18	0.03	0.002	-	-
ADFI, lb	1.80	1.74	1.64	1.62	0.04	0.009	-	-
F/G	1.42	1.34	1.38	1.40	0.02	-	-	0.03
Overall (0 to 28)								
ADG, lb	1.02	0.95	1.04	0.96	0.03	-	0.002	-
ADFI, lb	1.28	1.20	1.26	1.19	0.03	-	0.003	-
F/G	1.28	1.28	1.23	1.25	0.01	0.007	-	-

[a]A total of 192 pigs with an avg initial BW of 13.9 lb and an average starting age of 21d.
[b]Dashes indicate P = 0.15 or greater.

EVALUATION OF DIFFERENT SOY PROTEIN CONCENTRATE SOURCES ON GROWTH PERFORMANCE OF WEANLING PIGS[1]

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Summary

Three experiments were conducted using 486 weanling pigs (216 in Experiment 1; 210 in Experiment 2; 60 in Experiment 3) to determine the effects of different soy protein concentrate (SPC) sources on growth performance. Soy protein concentrate source 1 is dried with a torus disk following the concentration of soy proteins. This drying procedure will generate some degree of heat and possibly mechanical forces somewhat similar to extrusion processing (Soycomil P®, ADM). Soy protein concentrate source 2 is dried by a different process, and then it is moist extruded (Profine E, Central Soya). Therefore, the objective of our study was to determine the relative feeding value of the different SPC sources compared with a complex diet containing milk and other specialty proteins (no soy protein), or a diet containing 40% soybean meal.

In Experiment 1, each SPC source (28.6%) replaced all the soybean meal (SBM) in the control diet on a lysine basis. Pigs fed the diet containing 40% SBM had similar performance to pigs fed the milk-protein based diet from d 0 to 14. Pigs fed either SPC source had lower ADG and ADFI compared to pigs fed either the diet containing 40% SBM or the milk-protein based diet. Pigs fed the diet containing 40% SBM and SPC from source 2 had better F/G than pigs fed the milk-protein based diet or SPC from source 1.

In Experiment 2, either all or half of the soybean meal was replaced by the 28.6 or 14.3% SPC from source 1 and 2. From d 0 to 14 and d 0 to 28, an SPC source by level interaction was observed for ADG ($P<0.01$) and ADFI ($P<0.07$). Replacing soybean meal with SPC from source 1 did not influence pig performance. However, replacing soybean meal with SPC from source 2 resulted in a quadratic ($P<0.05$) improvement in ADG with performance being improved for the diet containing 14.3% SPC, but no benefit to replacing all the soybean meal with SPC. Replacing soybean meal with SPC from either source influenced feed efficiency in a quadratic ($P<0.01$) manner with feed efficiency being optimal for pigs consuming the diet with half the soybean meal replaced by SPC.

Because replacing all of the soybean meal with SPC reduced ADFI in Experiments 1 and 2, we hypothesized that pigs may not prefer the taste of a diet with a high inclusion rate of SPC (28.6%). To test this theory, a 7-day preference test was conducted to determine feed

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[2]Food Animal Health and Management Center.

feed intake of weanling pigs provided the option of consuming diets containing either 40% soybean meal or 28.6% SPC (from source 2). Average daily feed intake was 0.41 and 0.01 lb for the 40% soybean meal and 28.6% soy protein concentrate diets, respectively ($P<0.0001$). The poor intake of the SPC diet may indicate a palatability problem when high levels of SPC are included in the diet. Our results suggest replacing a portion of the soybean meal in the diet with SPC from source 2 improves ADG and feed efficiency; however, high levels (28.6%) of SPC should not be included in the diet.

Introduction

Commercial diets for early-weaned pigs currently contain relatively low levels of soybean meal. It has been suggested by researchers that the quantity of soybean meal in diets is limited by delayed-type hypersensitivity reactions of young pigs to high levels of soybean meal. However, if increased amounts of soybean meal could replace more expensive protein sources without affecting pig performance, this would be an economic advantage for producers. A greater inclusion of soy proteins may be possible without negatively affecting pig performance due to different processing methods of soybean meal. Further processed soy proteins such as soy protein concentrate and extruded soy protein concentrate – may be alternatives to animal-based protein sources.

Soy protein concentrates (SPC) are protein sources produced from defatted soy flakes. Soluble carbohydrates – primarily sucrose, raffinose, and stachyose – are removed from the defatted flakes. Soy protein concentrate source 1 is dried with a torus disk following the concentration of soy proteins. This drying procedure generates some degree of heat and possibly mechanical forces somewhat similar to extrusion processing (Soycomil P®, ADM). Soy protein concentrate source 2 is dried by a different process, then moist extruded (Profine E, Central Soya). The objective of our study was to determine the relative feeding value of the different SPC sources compared with a complex diet containing milk and other specialty proteins, or a diet containing 40% soybean meal.

Procedures

In Experiment 1, a total of 216 weanling pigs (each initially 14.7 lb and 18 d of age, PIC) were used in a 28-d growth assay. The pigs were blocked by initial weight and allotted to one of four dietary treatments in a randomized complete block design. All pigs were housed in the KSU Swine Teaching and Research Center's environmentally controlled nursery. Each pen contained six pigs, and there were nine replicate pens per treatment. Each pen contained a stainless steel self-feeder and one nipple waterer to allow ad libitum access to feed and water. The four treatments consisted of a positive control diet containing milk products and other specialty proteins, a negative control diet containing 40% soybean meal, and two diets containing SPC source 1 or 2 (Table 1). In each of these two diets, soybean meal was completely substituted by SPC on a lysine basis. Energy level across the diets was maintained constant at 1,554 ME, kcal/lb. Energy and amino acid values supplied by the manufacturers were used in diet formulation. An energy value of 1,874 ME kcal/lb was used for the SPC sources, while a value of 1,533 ME kcal/lb was used for soybean meal.

In Experiment 2, 210 weanling pigs (each initially 14.0 lb and 18 d of age) were used in a 28-d growth assay. Pens of pigs were randomly assigned to dietary treatments, similar to that in Experiment 1. There were six pigs per pen and seven pens per treatment. Each pen had ad libitum access to feed and water as in Experiment 1. There were five treatments used in Experiment 2. In addition to the diet containing 40% soybean meal and the SPC diets used in Experiment 1, two additional di-

ets of 14.3% SPC source 1 and 14.3% SPC source 2 were fed (Table 2). These diets replaced 50% of the soybean meal component. Energy was maintained at 1,513 kcal of ME per lb for all diets. For Experiment 2, a more conservative energy value of 1,533 ME kcal/lb was used for both SPC sources and soybean meal.

After analyzing Experiments 1 and 2, it appeared that feed intake had a large influence on results. To test the hypothesis that palatability was a problem with SPC, a total of 60 weanling gilts (each initial BW of 13.4 lb and 15 ± 2 d of age) were used in a 7-d preference trial. Pigs were offered a choice of eating the diet containing 40% SBM or the diet containing 28.6% SPC source 2. Pigs were blocked by weight and allotted to a pen containing two feeders to give a total of 10 pens with six pigs per pen. Pigs were housed at the Segregated Early Weaning Facility at Kansas State University. Each pen was 8 × 8 ft and contained two self-feeders and two nipple waterers to provide ad libitum access to feed and water. The placement of feeders in each pen was alternated twice daily to enable a more accurate portrayal of preference by the pigs for the diets. Pigs and feeders were weighed after 7 days in order to calculate ADFI. Temperature was maintained at approximately 92°F over the experiment's duration.

In both Experiment 1 and Experiment 2, experimental diets were fed from d 0 to d 14 after weaning. From d 14 to d 28, pigs were fed a common diet (Table 3). All diets were fed in meal form. The response criteria of ADG, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 7, 14, 21, and 28 of both experiments. Data were analyzed as a randomized complete block design with pen as the experimental unit using the MIXED procedure of SAS.

Results

From d 0 to 14 in Experiment 1, pigs fed the milk and specialty protein based diet and the diet containing 40% soybean meal had similar ADG, and both were greater than pigs fed either SPC source (Table 4). The improved performance in pigs fed the milk based protein diet and the diet containing 40% SBM appears to be a result of greater ADFI than pigs fed either SPC source. Pigs fed SPC source 2 had better F/G than pigs fed SPC source 1 and the milk protein-based diet, while those fed the diet containing 40% soybean meal had intermediate F/G.

From d 14 to 28, when all pigs were fed a common diet, protein source fed from d 0 to 14 after weaning had no effect on growth performance.

For the overall experimental period (d 0 to 28), pigs fed the diet containing 40% soybean meal or the milk protein-based diet from d 0 to 14 had greater ADG and ADFI than pigs fed either SPC source. No differences were seen in F/G among dietary treatments.

From d 0 to 14 in Experiment 2, there was an SPC source by level interaction ($P < 0.02$) for ADG and ADFI. Pigs fed the diet containing 14.3% SPC from source 2 had greater ADG than pigs fed other diets, resulting in a quadratic effect ($P<0.01$) of level for SPC from source 2. No improvement was seen when SPC from source 1 replaced soybean meal. The SPC source by level interaction for ADFI ($P<0.02$) was due to a linear reduction in ADFI for pigs from SPC from source 2. Feed efficiency improved ($P<0.01$) in a quadratic manner as increasing levels of SPC were added to the diet, with pigs fed the diets with 50% of the soybean meal replaced by SPC having the best F/G. Pigs fed SPC from source 2 also had improved ($P< 0.01$) F/G compared to pigs fed SPC from source 1.

When all pigs were fed the same diet from d 14 to 28, ADG of pigs that were fed 14.3% SPC from either source from d 0 to 14 tended ($P<0.09$) to be greater than pigs fed the other diets. Pigs fed SPC from source 1 from d 0 to 14 had improved ($P<0.03$) F/G from d 14 to 28 compared with pigs fed SPC from source 2 from d 0 to 14.

The response for the overall experiment (d 0 to 28) was similar to the response from d 0 to 14. Increasing SPC from source 2 resulted in a quadratic ($P<0.05$) improvement in ADG, with pigs fed 14.3% SPC from source 2 having the best ADG (SPC source by level interaction, $P<0.01$). Feed intake decreased (quadratic, $P<0.05$) as level of SPC from source 2 increased in the diet. Pigs fed SPC from source 2 had improved F/G compared to pigs fed SPC from source 1 ($P<0.013$). Feed efficiency also improved (quadratic, $P<0.01$) as level of SPC increased in the diet. Overall, pigs fed SPC from source 2 at a level of 14.3% of the diet outperformed pigs fed the other diets, showing the highest ADG and ADFI, in addition to the best F/G.

The reason for the similar performance of the milk protein-based diet compared with pigs fed 40% soybean meal in Experiment 1 is unknown. Trypsin inhibitor activity in soybean meal and SPC from source 1 and 2 (Experiment 1) was non-detectable, suggesting adequate processing. Urease activity also was shown to be negligible. Protein solubility values also were obtained for these diets with values of 80.06, 58.86, and 74.28 for soybean meal, SPC source 1, and SPC source 2, respectively. Values below 70% are suggestive of overprocessing, indicating that poorer performance of pigs fed SPC from source 1 may be due to overprocessing. Analysis of crude protein also was conducted on these diets. Crude protein content of the diet containing SPC from source was lower than expected, at 20.34% compared to the diet formulation value of 25%.

In Experiment 1, it appeared that feed intake was responsible for the differences in ADG. Over the experimental period, both ADG and ADFI in pigs fed SPC was lower than in pigs fed the milk protein-based diet and the diet containing 40% soybean meal. These data suggest that it is not possible to replace all the soybean meal in the diet with SPC because a depression in intake results, presumably because pigs find it unpalatable at high levels, as shown by the preference trial.

In Experiment 2, there was a large difference observed in pigs fed different sources of SPC. While pigs fed the diet with 14.3% SPC from source 2 showed the best performance, an unknown adverse effect appears to be induced with the higher level of 28.6% SPC from source 2. Pigs fed SPC source 1 performed more poorly than SPC from source 2. From the data, it is apparent that SPC from source 1 cannot be included in the diet at as high a level as SPC from source 2.

Overall, the pigs grew faster in the second experiment. This finding may be partly due to the method of diet formulation. In formulating the diets for Experiment 1, a value for energy of 1,874 ME, kcal/lb was used for both SPC sources, taken from the manufacturer's suggested nutrient profile. It is possible that we overestimated the energy value of the SPC sources in Experiment 1, so a more conservative energy value of 1,533 ME, kcal/lb was used for both SPC sources in Experiment 2.

In the preference trial, preference by the pigs for 40% soybean meal quickly became apparent during the duration of the 7-d trial (Table 6). Average daily feed consumption was 0.41 and 0.01 lb for the 40% soybean meal and 28.6% SPC from source 2 diets, respectively ($P<0.0001$).

In conclusion, these experiments do not reflect previous work carried out by other researchers on this topic. We did not see the

much-reported greater performance in nursery pigs when protein from milk sources is used in diets rather than protein from soybean meal. It appears that soybean meal diets can perform as effectively as more complex diets when considering the age, weight, and health status of pigs in our studies. Regarding sources of soy protein concentrate, we predict that there is a certain level to which they can be substituted for soybean meal. Substitution above that amount results in a decrease in performance. The results of the preference trial suggest a palatability problem when SPC completely replaces soybean meal in the diet. Further research needs to be completed regarding the optimum level at which sources of soy protein concentrate can be included in nursery pig diets.

Table 1. Diet Composition, Experiment 1

			SPC	
Ingredient, %	Control	40% Soybean meal	Source 1	Source 2
Corn	55.01	31.18	46.88	46.88
Soybean meal, 46.5%	---	40.0	---	---
Soy protein concentrate source[a]	---	---	28.55	28.55
Spray-dried animal plasma	8.60	---	---	---
Select menhaden fishmeal	7.50	---	---	---
Spray-dried blood meal	2.50	---	---	---
Spray dried whey	20.0	20.0	20.0	20.0
Soy oil	2.85	4.30	---	---
Monocalcium phosphate, 21% P	0.55	1.40	1.45	1.45
Limestone	0.60	0.90	0.975	0.975
Salt	0.30	0.30	0.30	0.30
Vitamin premix	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15
Medication[b]	1.00	1.00	1.00	1.00
Zinc oxide	0.375	0.375	0.375	0.375
L-isoleucine	0.185	---	---	---
Lysine HCl	0.03	0.05	---	---
DL-methionine	0.10	0.10	0.075	0.075
Total	100.0	100.0	100.0	100.0
Total lysine, %	1.51	1.51	1.51	1.51
Isoleucine:lysine ratio, %	60	71	77	77
Leucine:lysine ratio, %	137	132	143	143
Methionine:lysine ratio, %	29	30	30	30
Met & Cys:lysine ratio, %	58	57	57	57
Threonine:lysine ratio, %	6%	65	70	70
Tryptophan:lysine ratio, %	18	21	19	19
Valine:lysine ratio, %	79	76	84	84
ME, kcal/lb	1,554	1,554	1,554	1,554
Protein, %	20.8	23.7	25.0	25.0
Ca, %	0.90	0.90	0.90	0.90
P, %	0.80	0.80	0.80	0.80
Lysine:calorie ratio, g/mcal	4.41	4.41	4.41	4.41

[a]An energy value of 1,874 ME kcal/lb was used for both SPC sources.
[b]Provided 50g/ton carbadox.

Table 2. Diet Composition, Experiment 2

		SPC[a]	
Ingredient, %	40% Soybean meal	14%	28%
Corn	32.98	38.68	44.40
Soybean meal, 46.5%	40.00	20.00	---
Soy protein concentrate source[b]	---	14.28	28.55
Spray dried whey	20.00	20.00	20.00
Soy oil	2.50	2.50	2.50
Monocalcium phosphate, 21% P	1.38	1.40	1.40
Limestone	0.925	0.95	0.975
Salt	0.30	0.30	0.30
Vitamin premix	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15
Medication[c]	1.00	1.00	1.00
Zinc oxide	0.375	0.375	0.375
Lysine HCl	0.05	0.03	0.01
DL-methionine	0.10	0.09	0.09
Total	100.0	100.0	100.0
Total lysine, %	1.51	1.51	1.51
Isoleucine:lysine ratio, %	72	74	77
Leucine:lysine ratio, %	133	137	142
Methionine:lysine ratio, %	30	30	30
Met & Cys:lysine ratio, %	57	57	57
Threonine:lysine ratio, %	65	67	70
Tryptophan:lysine ratio, %	21	20	19
Valine:lysine ratio, %	77	80	83
ME, kcal/lb	1,513	1,513	1,513
Protein, %	23.8	24.3	24.8
Ca, %	0.90	0.90	0.90
P, %	0.80	0.80	0.80
Lysine:calorie ratio, g/mcal	4.53	4.53	4.53

[a]14.3% and 28.6% of both SPC sources.
[b]An energy value of 1,533 ME kcal/lb was used for both SPC sources.
[c]Provided 50g/ton carbadox.

Table 3. Composition of Common Diet Fed From D 14 to 28 in Experiments 1 and 2

Ingredient, %	
Corn	51.17
Soybean meal, 46.5%	27.30
Soy oil	3.00
Monocalcium phosphate, 21% P	0.90
Limestone	0.60
Salt	0.30
Vitamin premix	0.25
Trace mineral premix	0.15
Medication[a]	1.00
Zinc oxide	0.25
L-threonine	0.13
Lysine HCl	0.30
DL-methionine	0.15
Select menhaden fishmeal	4.50
Spray dried whey	10.00
Total	100.00
Total lysine, %	1.50
Isoleucine:lysine ratio, %	61
Leucine:lysine, %	121
Methionine:lysine, %	34
Met & Cys:lysine ratio, %	58
Threonine:lysine ratio, %	65
Tryptophan:lysine, %	17
Valine:lysine, %	68
ME, kcal/lb	1,546
Protein, %	21.1
Ca, %	0.81
P, %	0.73
Lysine:calorie ratio, g/mcal	4.40

[a]Provided 50g/ton carbadox.

Table 4. Effect Of Different Soy Protein Concentrate Sources on Growth Performance of Weanling Pigs (Experiment 1)[abc]

Item	Control	40% Soybean Meal	28.6% SPC Source 1	28.6% SPC Source 2	SED
Day 0 to 14					
ADG, lb	0.694[d]	0.694[d]	0.544[e]	0.561[e]	0.035
ADFI, lb	0.864[d]	0.806[d]	0.672[e]	0.641[e]	0.040
Feed:Gain	1.231[de]	1.157[ef]	1.251[d]	1.146[f]	0.029
Day 14 to 28					
ADG, lb	1.162	1.181	1.141	1.123	0.043
ADFI, lb	1.595	1.634	1.529	1.510	0.045
Feed:Gain	1.379	1.388	1.343	1.355	0.039
Day 0 to 28					
ADG, lb	0.928[d]	0.937[d]	0.843[e]	0.842[e]	0.028
ADFI, lb	1.229[d]	1.220[d]	1.101[e]	1.075[e]	0.035
Feed:Gain	1.305	1.272	1.297	1.250	0.021

[a]A total of 216 pigs (6 pigs per pen) with an initial average BW of 14.7 lb.
[b]Treatment diets were fed from d 0 to 14.
[c]Common diet fed from d 14 to 28.
[def]Means in the same row with different superscripts differ ($P<0.05$).

Table 5. Effect Of Different Soy Protein Concentrate Sources On Growth Performance Of Weanling Pigs (Experiment 2)[abc]

Item	40% Soy-bean meal	SPC Source 1		SPC Source 2		SED	Probability (P<)		
		14.3%	28.6%	14.3%	28.6%		SPC Level	Soy Source	Level x Source
Day 0 to 14									
ADG, lb[de]	0.762	0.711	0.707	0.827	0.687	0.036	0.01	0.07	0.01
ADFI, lb[d]	0.918	0.847	0.876	0.914	0.780	0.044	0.11	0.65	0.02
Feed:Gain[f]	1.182	1.168	1.220	1.078	1.105	0.022	0.03	0.01	0.49
Day 14 to 28									
ADG, lb	1.077	1.126	1.115	1.142	1.066	0.036	0.09	0.53	0.20
ADFI, lb	1.539	1.584	1.557	1.618	1.554	0.044	0.17	0.64	0.57
Feed:Gain	1.429	1.406	1.398	1.417	1.466	0.022	0.26	0.03	0.11
Day 0 to 28									
ADG, lb[e]	0.920	0.918	0.911	0.984	0.876	0.031	0.01	0.40	0.01
ADFI, lb[e]	1.228	1.215	1.217	1.266	1.167	0.039	0.08	0.99	0.07
Feed:Gain[f]	1.306	1.287	1.309	1.248	1.286	0.017	0.02	0.02	0.50

[a]A total of 210 pigs (6 pigs per pen) with an initial average BW of 14.0 lb.
[b]Treatment diets were fed from d 0 to 14.
[c]Common diet fed from d 14 to 28.
[d]Linear effect for soy source 2 (P<0.05).
[e]Quadratic effect for soy source 2 (P<0.05).
[f]Quadratic effect of soy level (P<0.01).

Table 6. Preference Of Weanling Pigs For 40% Soybean Meal vs 28% Soy Protein Concentrate[a]

Item	40% Soybean meal	28% SPC Source	P <	SED
Day 0 to 7				
ADFI, lb	0.41[b]	0.01[c]	<.0001	0.02

[a]A total of 60 pigs (6 pigs per pen) with an initial average BW of 13.4 lb.
[bc]Means in same row with different superscripts differ (P<0.01).

EFFECTS OF EXTRUDED-EXPELLED SOYBEAN MEAL AND SOLVENT EXTRACTED SOYBEAN MEAL LEVEL OF GROWTH PERFORMANCE OF WEANLING PIGS[1,2]

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Summary

A total of 350 weanling pigs (initially 15.7 lb) were used to evaluate the effects of soybean meal source and level on growth performance of early weaned pigs. Dietary treatments included a control diet containing no soybean meal, or diets containing 20% or 40% of either solvent extracted soybean meal (SBM) or extruded-expelled soybean meal (EESOY). The SBM and EESOY were analyzed for trypsin inhibitor (0.7 mg TI/g and 1.8 mg TI/g, respectively) to ensure quality, and actual crude protein values (46.9% and 48.3% as-fed, respectively) were used in diet formulation. From d 0 to 14, increasing EESOY decreased ADG and ADFI (linear, $P<0.01$), but improved F/G (linear, $P<0.05$). Increasing SBM decreased ADFI (linear, $P<0.02$), but improved F/G (linear, $P<0.01$). No differences ($P>0.05$) were found between soybean meal sources throughout the trial. The results of this study suggest extruded-expelled soybean meal processed properly and fed in diets immediately after weaning did not improve growth performance of nursery pigs relative to conventional solvent extracted soybean meal. When EESOY or SBM was included at 40% in diets fed immediately after weaning, growth performance of weanling pigs was poorer than if fed at lower levels (20%). Feeding properly processed EESOY resulted in similar growth performance compared to feeding SBM.

(Key Words: Weanling Pigs, Soybean Meal, Performance)

Introduction

The amount of soybean meal in diets fed immediately after weaning is usually limited because of delayed-type hypersensitivity reactions of young pigs to high levels of glycinin and beta conglycinin found in soybean meal. However, it is important to include some soybean meal in the initial diets in order to acclimate pigs to soy protein so that levels of soybean meal can be increased in later diets. Processing methods of soybean meal, such as extruding and expelling, may allow for greater inclusions of soy proteins in the diet without negatively affecting pig performance. Previous research at Kansas State University has

[1]Appreciation is expressed to North Central Processors, Washington, Kansas, for providing the extruded-expelled soybean meal.
[2]Appreciation is expressed to S. Hanni, B. James, M. Young, M. Barker, and T. Rathbun for their assistance in data collection.
[3]Food Animal Health and Management Center.

shown that moist extrusion of soybean meal can result in growth performance comparable to and better than that achieved by feeding highly refined soy products to the early-weaned pig. The dry extrusion-expelling technique (Insta-Pro Express Extruder/Press System, Des Moines, Iowa) results in a soybean meal with higher fat (oil) content than solvent extracted processed soybean meal. The high temperature of the extrusion technology aids in the inactivation of anti-nutritional factors, such as conglycinin and β-conglycinin, which are potentially antigenic with the intestinal lumen.

Previous research has shown that pigs (>25 lb) fed extruded-expelled soybean meal have equal or better growth performance than pigs fed solvent extracted soybean meal.

The objective of studies reported in a previous Kansas State University Swine Day Report (2002) were to evaluate the nutritional value of EESOY relative to SBM. Reports in the 2002 KSU Swine Day showed that pigs fed EESOY performed poorer than pigs fed SBM due to high levels of trypsin inhibitor (>8.2 mg TI/g) in the EESOY. Therefore, the objective of this study was to evaluate the nutritional value of properly processed extruded-expelled soybean meal (<5 mg TI/g) relative to soybean meal in diets fed to pigs immediately after weaning.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved all experimental protocols used in this study.

Three hundred and fifty barrows and gilts (initially 15.7 ± 6.0 lb and 21 ± 3 d of age at weaning) were blocked by weight and allotted randomly to one of five dietary treatments which were fed from d 0 to 14 after weaning (Table 1) and a common Phase II diet was fed from d 14 to 21 (Table 2). Each treatment had 14 replications (pens) per treatment and five pigs per pen. Diets were formulated with actual analyzed nutrient soybean meal values. Dietary treatments included a control diet containing no soybean meal, or diets containing 20% or 40% soybean meal or extruded-expelled soybean meal. Soybean meal replaced all or 50% of the spray-dried animal plasma, fishmeal and blood meal in diets containing 20% and 40% soybean meal product. All diets for each experiment were formulated to meet or exceed the nutrient requirement estimates of pigs suggested by the NRC, respectively (1998).

Pigs were housed at the Kansas State University Segregated Early Wean Facility. Each pen was 4 × 4 ft and contained one self feeder and one nipple waterer to allow ad libitum access to feed and water. Room temperature was initially 35ºC then lowered 2ºC each week based on pig comfort. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance every 7 days.

Data were analyzed using the MIXED procedures of SAS as a randomized complete block design with pen as the experimental unit. Linear and quadratic contrasts were determined for each source of soybean meal and contrasts determined if there were any differences between soybean meal sources.

Results

Crude protein and trypsin inhibitor values for the SBM and EESOY were analyzed prior to the experiment (SBM, 46.9% CP, 0.7 mg TI/g; EESOY, 48.3% CP, 1.8 mg TI/g) to validate adequate processing. From d 0 to 7, increasing extruded-expelled soybean meal decreased (linear, $P<0.04$) ADG and ADFI (Table 3). Increasing solvent extracted soybean meal decreased (linear, $P<0.04$) ADFI.

From d 7 to 14 similar results were seen with increasing extruded-expelled soybean meal. As extruded-expelled soybean meal increased, ADG and ADFI decreased (linear, $P<0.03$). For the overall treatment period (d 0 to 14), increasing extruded-expelled soybean meal decreased ADG, ADFI, (linear, $P<0.01$) and improved F/G (linear, $P<0.05$), while increasing solvent extracted soybean meal decreased ADFI (linear, $P<0.02$) and improved F:G (linear, $P<0.01$). For the common period (d 14 to 21), increasing either soybean meal source in the treatment period increased ADG and ADFI (linear, $P<0.01$). For the overall period (d 0 to 21), increasing either soybean meal source improved feed efficiency (linear, $P<0.02$). No differences were observed ($P>0.05$) between growth performance of pigs fed solvent extracted soybean meal or extruded-expelled soybean meal.

Discussion

Results reported of previous trials (Swine Day 2002) suggest that the extruded-expelled soybean meal contained levels of trypsin inhibitor (Exp. 1, 9.3 mg TI/g; Exp. 2, 8.2 mg TI/g) higher than conventional solvent extracted soybean meal (Exp. 1, 1.2 mg TI/g; Exp. 2, 2.0 mg TI/g). This is speculated to be because of the lower moisture level of the whole soybeans used for the extruded-expelled process. The soybeans used in these trials were grown in a relatively dry year and the moisture content of the beans at harvest was lower than average. Moisture needed to be added back to the raw soybeans before processing. For this third experiment, the soybeans used for the extruded-expelled soybean meal were tested for moisture before the raw soybeans were processed to ensure adequate moisture level of the soybeans for processing to help cook the soybeans and deactivate the trypsin inhibitor. The trypsin inhibitor values of the extruded-expelled soybean meal were lowered greatly after the moisture content of the raw soybeans was monitored (1.8 mg TI/g).

Quality control steps of extruded-expelled soybean meal production assure optimum quality of the product. Moisture and temperature are very important to deactivate anti-nutritional factors. Therefore, to reduce the trypsin inhibitor units to an acceptable level with low moisture raw beans, the temperature will need to be increased compared to that of soybeans containing a higher moisture level. Alternatively, moisture could be added to the soybeans. Checking the trypsin inhibitor level of raw soybeans may be useful in determining the proper level of moisture to be added or proper temperature to be used. It is important for EESOY manufacturers to establish a quality control procedure that assures optimum quality of EESOY and proper destruction of anti-nutritional factors.

Previous research at Kansas State University has found dry extruded-expelled soybean meal with or without hulls has greater apparent ileal digestibilities of amino acids and greater digestible and ME than commercially-available, solvent extracted soybean meal. Growth performance of pigs fed dry extruded-expelled soybean meal or solvent extracted soybean meal was similar when diets were formulated on the basis of equal apparent ileal digestible lysine and ME, suggesting that the dry extruder-expeller inactivates the anti-nutritional factors associated with raw soybeans. We found no differences between soybean meal sources when the extruded-expelled soybean meal was adequately processed.

Currently, commercial diets for the early weaned pig contain relatively low levels of soybean meal to minimize the transient hypersensitivity and maximize growth. We had initially hypothesized that the extrusion process may inactivate more of the antigens compared to the solvent extracted soybean meal process.

The results of our experiments are in agreement with previous research suggesting adequate levels of extruded-expelled soybean meal and solvent extracted soybean meal in the weanling pig diet to be approximately 20%. We found that soybean meal source levels of 40% in the diet decreased growth performance of nursery pigs compared to a 20% inclusion rate. Subsequent performance of pigs previously fed 40% soybean meal source had no compensatory growth.

Our results indicate the EESOY was not superior to the solvent extracted soybean meal. Our studies suggest that extruded-expelled soybean meal has similar feeding value compared to solvent extracted soybean meal if the extruded-expelled soybean meal is adequately processed to destroy anti-nutritional factors such as trypsin inhibitor. Increasing levels of either soybean meal source decreased growth performance in weanling pigs immediately after weaning.

In conclusion, extruded-expelled soybean meal production should be monitored closely to ensure destruction of anti-nutritional factors. Pigs fed diets containing properly processed extruded-expelled soybean meal had similar growth rates and feed efficiency compared to pigs fed solvent extracted soybean meal. Therefore, when properly processed, either source of soybean meal is acceptable for early-weaned nursery pig diets. Price and product availability should determine the soybean meal source to be included in nursery diets.

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

		Soybean meal source			
		Solvent extracted		Extruded-expelled	
Ingredient, %	Control	20%	40%	20%	40%
Corn	50.89	38.75	26.47	40.94	30.85
Soybean meal	-	20.00	40.00	20.00	40.00
Spray-dried whey	22.50	22.50	22.50	22.50	22.50
Fishmeal	8.63	4.94	1.25	4.44	0.25
Spray-dried animal plasma	8.60	4.30	-	4.30	-
Soy oil	3.90	4.73	5.55	2.95	2.00
Spray-dried blood meal	2.50	1.25	-	1.25	-
Medication[b]	1.00	1.00	1.00	1.00	1.00
Monocalcium phosphate, 21% P	-	0.73	1.45	0.78	1.55
Limestone	0.60	0.60	0.60	0.64	0.67
Zinc oxide	0.38	0.38	0.38	0.38	0.38
Salt	0.30	0.30	0.30	0.30	0.30
Vitamin premix	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
L-isoleucine	0.20	0.02	-	0.02	-
DL-methionine	0.10	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
Lysine, %	1.55	1.55	1.55	1.55	1.55
Ile:lys ratio, %	60	60	71	60	72
Met Cys:lys ratio, %	58	58	57	58	58
Thr:lys ratio, %	66	66	66	66	66
Trp:lys ratio, %	18	20	21	20	21
Val:lys ratio, %	79	78	77	79	78
ME, kcal/lb	1,581	1,582	1,580	1,583	1582
Protein, %	21.7	23.0	24.5	23.2	24.8
Ca, %	0.87	0.87	0.87	0.87	0.87
P, %	0.72	0.79	0.85	0.79	0.86
Available P, %	0.57	0.57	0.57	0.57	0.57
Lysine:calorie ratio, g/Mcal	4.45	4.45	4.45	4.45	4.45

[a]Diets were formulated on actual analyzed crude protein values of soybean meal. The solvent extracted soybean meal contained 46.9% crude protein and the extruded-expelled soybean meal contained 48.3% crude protein.
[b]Provided 50 g/ton of carbadox.

Table 2. Composition of Common Diet (As-fed Basis)[a]

Ingredient, %	Phase II
Corn	50.04
Soybean meal, 46.5% CP	27.20
Spray-dried whey	10.00
Select menhaden fishmeal	5.00
Soy oil	4.00
Medication[b]	1.00
Monocalcium phosphate, 21% P	0.98
Limestone	0.65
Zinc oxide	0.25
Vitamin premix	0.25
Salt	0.25
Trace mineral premix	0.15
L-lysine HCl	0.15
DL-methionine	0.08
Calculated Analysis	
Lysine, %	1.40
Met:lys ratio, %	32
Met Cys:lys ratio, %	57
Thr:lys ratio, %	61
Trp:lys ratio, %	18
ME, kcal/lb	1,560
CP, %	21.3
Ca, %	0.87
P, %	0.76
Available P, %	0.48

[a]Phase II common diet was fed from d 14 to 21.
[b]Provided 50 g/ton of carbadox.

Table 3. Effects of Extruded-Expelled Soybean Meal and Solvent Extracted Soybean Meal Level on Growth Performance of Weanling Pigs[a]

	Treatments						Probability, P<				
		Soybean meal source					Soybean meal source				
		Solvent extracted		Extruded-expelled			Solvent-extracted		Extruded-expelled		SBM vs.
Item	Control	20%	40%	20%	40%	SE	Linear	Quadratic	Linear	Quadratic	EESOY
Day 0 to 7											
ADG, lb	0.63	0.62	0.62	0.55	0.53	0.04	0.11	0.48	0.04	0.34	0.72
ADFI, lb	0.56	0.52	0.52	0.46	0.44	0.04	0.04	0.74	0.02	0.66	0.81
F/G	0.89	0.84	0.84	0.84	0.85	0.03	0.20	0.43	0.26	0.31	0.99
Day 7 to 14											
ADG, lb	0.72	0.69	0.68	0.69	0.61	0.04	0.57	0.82	0.03	0.71	0.19
ADFI, lb	0.80	0.76	0.75	0.72	0.67	0.04	0.11	0.95	0.01	0.74	0.37
F/G	1.14	1.10	1.11	1.07	1.10	0.03	0.06	0.89	0.31	0.82	0.38
Day 0 to 14[b]											
ADG, lb	0.67	0.66	0.62	0.65	0.57	0.03	0.10	0.71	0.01	0.30	0.20
ADFI, lb	0.68	0.64	0.59	0.63	0.56	0.03	0.02	0.86	0.01	0.61	0.45
F/G	1.02	0.97	0.96	0.98	0.98	0.02	0.01	0.41	0.05	0.26	0.42
Day 14 to 21[c]											
ADG, lb	1.06	1.10	1.12	1.22	1.27	0.04	0.01	0.36	0.01	0.34	0.32
ADFI, lb	1.29	1.29	1.30	1.46	1.46	0.04	0.01	0.05	0.01	0.11	0.87
F/G	1.22	1.18	1.17	1.22	1.17	0.03	0.97	0.27	0.16	0.40	0.20
Day 0 to 21											
ADG, lb	0.80	0.80	0.82	0.81	0.80	0.03	0.49	0.78	0.99	0.81	0.67
ADFI, lb	0.88	0.86	0.88	0.86	0.86	0.03	0.99	0.37	0.45	0.67	0.61
F/G	1.08	1.04	1.04	1.04	1.04	0.01	0.02	0.13	0.01	0.11	0.77

[a]A total of 350 pigs (five pigs per pen and fourteen pens per treatment) with an average initial BW of 15.7 lb.
[b]Treatment diets were fed from d 0 to 14 of the experiment.
[c]Day 14 to 21 pigs were fed common Phase II diet.

THE EFFECTS OF POULTRY MEAL AND FISHMEAL ON GROWTH PERFORMANCE OF WEANLING PIGS[1]

T.P. Keegan, J.L. Nelssen, J.M. DeRouchey, R.D. Goodband, M.D. Tokach, and S.S. Dritz[2]

Summary

A total of 210 weanling pigs (initially 16.4 lb and 21 ± 2 d of age, PIC) was used to evaluate the effects of select menhaden fishmeal and stabilized poultry meal on growth performance of nursery pigs. Five dietary treatments were fed from d 0 to 28 after weaning. Diets included a control with no specialty protein products and diets with 2.5% and 5.0% fishmeal and poultry meal replacing the lysine provide by fishmeal at 2.9% and 5.9%. All the diets were formulated on an equal lysine basis. Overall (d 0 to 28), pigs fed diets containing fishmeal had greater ($P < 0.05$) ADG compared to pigs fed the control diet and pigs fed diets containing poultry meal. Also, increasing fishmeal tended (quadratic, $P<0.07$) to improve ADG, with the greatest increase observed in pigs fed 2.5% fishmeal. Feed intake was not affected by any dietary treatment. Pigs fed diets containing select menhaden fishmeal had improved ($P<0.05$) feed efficiency compared to pigs fed diets containing stabilized poultry meal. In conclusion, the addition of fishmeal to the diet improved the growth performance of weanling pigs, while stabilized poultry protein meal did not affect growth performance.

(Key Words: Poultry Meal, Weanling Pigs, Fishmeal.)

Introduction

The use of complex nursery diets with highly digestible ingredients has increased the need for specialty protein products, such as select menhaden fishmeal. However, specialty protein sources such as fishmeal are relatively expensive. Therefore, other specialty protein sources that have the potential to reduce diet cost without decreasing performance must be explored. Poultry meal is a by-product from poultry harvesting facilities that has a similar crude protein and amino acid profile to that of select menhaden fishmeal. Recent advancements in processing and quality control of the stabilized poultry meal have improved the consistency and palatability of the final product. Poultry meal is readily available and is currently used in the pet food and poultry industries.

A previous trial conducted at Kansas State University showed no response in growth performance for pigs fed fishmeal or poultry meal compared to pigs fed diets without any specialty protein products. This suggested that the use of whey was adequate for maximum growth of pigs in this particular environment. Therefore, the objective of this experiment was to compare the effects of select menhaden fishmeal and stabilized poultry meal on the growth performance of nursery pigs in a con-

[1]Appreciation is expressed to American Proteins Inc. (Cumming, Georgia) for supplying the stabilized poultry meal.

[2]Food Animal Health and Management Center.

trolled research setting without the use of animal plasma, blood products, or high levels of dried whey.

Procedures

A total of 210 pigs (initially 16.4 lb and 21 ± 2 d of age, PIC) was used in a 28-d growth assay. Pigs were blocked by weight and allotted to one of five dietary treatments at weaning. There were eight replicates (two replicates with six pigs per pen and six replicates with five pigs per pen) per treatment. Pigs were housed in an environmentally controlled nursery at the KSU Swine Teaching and Research farm. All pens (4 x 5 ft) contained one self-feeder and one nipple waterer to provide ad libitum access to feed and water.

The select menhaden fishmeal, stabilized poultry meal, and soybean meal were analyzed for amino acids, Ca, and P before being used in diet formulation (Table 1). Pigs were fed one of five dietary treatments, which included a control diet with no specialty protein products, and diets containing 2.5% or 5% fishmeal, and stabilized poultry meal replacing the lysine provided by fishmeal at the inclusion rates of 2.9% or 5.9%. All diets were corn-soybean meal based and included 10% edible grade spray-dried whey and were formulated to contain 1.45% total lysine, 0.90% Ca, and 0.75% P (Table 2). Average daily gain, ADFI, and feed efficiency (F/G) were determined by weighing pigs and measuring feed disappearance on d 7, 14, 21, and 28 post weaning.

Data were analyzed as a randomized complete block design using the mixed procedure of SAS with pen as the experimental unit. Single degree of freedom contrasts were used to compare performance of pigs fed the control diet to those fed the diets containing fishmeal or diets containing the different quality poultry meal. An additional contrast was used to compare pigs fed the fishmeal diets to those fed poultry meal. Linear and quadratic comparisons were used to determine the effects of feeding increasing levels of fishmeal or poultry meal.

Results and Discussion

From d 0 to 14, pigs fed fishmeal tended ($P<0.10$) to have greater ADG than pig fed stabilized poultry meal. Also, increasing fishmeal tended ($P<0.10$) to increase ADG with the greatest improvement observed in pigs fed 2.5% fishmeal. Pigs fed diets containing fishmeal had improved ($P<0.05$) feed efficiency compared to pigs fed diets containing stabilized poultry meal. Increasing poultry meal tended to result in poorer efficiency (linear, $P<0.08$).

From d 14 to 28, pigs fed diets containing fishmeal had greater ($P<0.05$) ADG compared to pigs fed the control diet or diets containing poultry meal. Also, increasing fishmeal increased (linear, $P<0.05$) ADG. Pigs fed diets containing fishmeal had improved ($P<0.05$) feed efficiency compared to pigs fed diets containing stabilized poultry meal.

For the overall treatment period (d 0 to 28), pigs fed diets containing fishmeal had greater ($P<0.05$) ADG than the pigs fed the control diet without any specialty protein products or diets containing poultry meal. Increasing fishmeal tended to result in improved (quadratic, $P<0.07$) ADG, with the greatest improvement observed in pigs fed the diet containing 2.5% fishmeal. Pigs fed diets containing fishmeal had improved ($P<0.01$) feed efficiency compared to pigs fed diets containing stabilized poultry meal. Increasing the stabilized poultry meal in the diet tended to result in poorer feed efficiency (linear, $P<0.09$).

Consistent with many previous trials, these results indicate that the addition of select menhaden fishmeal to diets improved the growth performance of weanling pigs. However, the use of stabilized poultry protein meal did not improve pig performance compared to

those fed the control diet without specialty proteins. Because adding stabilized poultry meal to the diet had a negative affect on feed efficiency without impacting feed intake, it appears that the amino acid availability of the poultry product may be lower than that of fishmeal or soybean meal.

Table 1. Chemical Analysis (As-fed Basis)[a]

Item, %	Stabilized Poultry Meal	Select Menhaden Fish-meal	Soybean Meal
CP	63.46	61.21	48.30
Ca	2.78	4.27	0.36
P	1.91	2.83	0.64
Lysine	4.30	5.01	3.03
Isoleucine	2.59	2.55	2.23
Leucine	4.62	4.55	3.76
Methionine	1.34	1.78	0.71
Met. and cys.	2.08	2.34	1.50
Threonine	2.46	2.52	1.87
Tryptophan	0.70	0.67	0.68
Valine	3.23	3.06	2.42

[a]Values represent the analysis of one sample of each ingredient.

Table 2. Diet Composition (As-Fed Basis)[a]

		Select Menhaden Fishmeal		Stabilized Poultry Meal[b]	
Item, %	Control	2.5%	5.0%	2.9%	5.9%
Corn	45.41	47.56	49.72	47.04	48.69
Soybean meal, 46.5%	34.50	30.18	25.87	30.19	25.87
Spray dried whey	10.00	10.00	10.00	10.00	10.00
Select menhaden fishmeal	-	2.50	5.00	-	-
Stabilized poultry meal	-	-	-	2.95	5.90
Soybean oil	5.00	5.00	5.00	5.00	5.00
Monocalcium phosphate, 21% P	1.55	1.35	1.10	1.35	1.18
Limestone	1.05	0.90	0.80	0.98	0.88
Antibiotic[c]	1.00	1.00	1.00	1.00	1.00
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
Zinc oxide	0.25	0.25	0.25	0.25	0.25
Lysine HCl	0.25	0.25	0.25	0.25	0.25
DL-Methionine	0.15	0.15	0.15	0.15	0.14
TOTAL	100.00	100.00	100.00	100.00	100.00
Calculated Values, %					
Lysine	1.45	1.45	1.45	1.45	1.45
Isoleucine:lysine ratio	66	64	62	65	64
Leucine:lysine ratio	128	126	124	127	126
Methionine:lysine ratio	33	35	36	34	35
Met & Cys:lysine ratio	60	60	60	60	60
Threonine:lysine ratio	65	65	65	65	65
Tryptophan:lysine ratio	19	19	18	19	18
Valine:lysine ratio	74	73	71	74	73
CP	21.73	21.36	20.99	21.71	21.68
Ca	0.90	0.90	0.90	0.9	0.90
P	0.75	0.75	0.75	0.75	0.75

[a]Pigs fed diets from d 0 to 28 after weaning.
[s]Stabilized poultry meal inclusion rates were based off the lysine provided by fishmeal.
[c]Provided 50g/ton carbadox.

Table 3. Effects of Stabilized Poultry Meal on Growth Performance of Weanling Pigs[a]

								Contrast (P <)						
		Fishmeal		Poultry Meal[c]				Control vs.		Fish vs.	Fishmeal		Poultry Meal	
	Control[b]	2.5%	5.0%	2.9%	5.9%	SE	TRT[d]	Fish	Poultry	Poultry	Linear	Quad.	Linear	Quad.
D 0 to 14														
ADG, lb	0.50	0.55	0.51	0.48	0.51	0.031	0.22	0.29	0.78	0.10	0.78	0.10	0.75	0.27
ADFI, lb	0.59	0.61	0.59	0.57	0.64	0.038	0.40	0.71	0.61	0.87	0.96	0.50	0.17	0.18
F/G	1.18	1.11	1.16	1.21	1.26	0.046	0.03	0.30	0.18	0.01	0.74	0.13	0.08	0.70
D 14 to 28														
ADG, lb	1.26	1.33	1.33	1.28	1.27	0.034	0.08	0.02	0.60	0.02	0.03	0.20	0.73	0.64
ADFI, lb	1.43	1.48	1.47	1.48	1.49	0.060	0.87	0.41	0.29	0.77	0.56	0.54	0.34	0.64
F/G	1.14	1.11	1.10	1.16	1.17	0.034	0.13	0.24	0.30	0.01	0.25	0.74	0.29	0.82
D 0 to 28														
ADG, lb	0.88	0.94	0.92	0.88	0.89	0.025	0.06	0.02	0.85	0.01	0.11	0.07	0.68	0.73
ADFI, lb	1.01	1.05	1.03	1.03	1.06	0.044	0.76	0.47	0.35	0.79	0.67	0.48	0.22	0.79
F/G	1.15	1.11	1.11	1.17	1.20	0.030	0.02	0.18	0.15	0.01	0.29	0.37	0.09	0.97

[a]A total of 210 pigs initially 16.4 lb and 18 ± 3 d of age (two replications with six pigs per pen and six replications with five pigs per pen).
[b]Control diet contained no fishmeal or poultry meal.
[c]Stabilized poultry meal inclusion rates were based off the lysine provided by fishmeal.
[d]P-value represents overall treatment effects.

THE EFFECTS OF POULTRY MEAL SOURCE ON GROWTH PERFORMANCE OF WEANLING PIGS[1]

T.P. Keegan, J.L. Nelssen, J.M. DeRouchey, R.D. Goodband, M.D. Tokach, S.S. Dritz[2], and C.W. Hasted

Summary

A total of 350 pigs (PIC, initially 19.7 lb and 22 ± 2 d of age) was used to evaluate the effects of select menhaden fishmeal and stabilized poultry meal source on growth performance of nursery pigs. Seven dietary treatments were fed from d 4 to 19 after weaning. Diets included a control with no specialty protein products and diets with 2.5% or 5% fishmeal, or two different sources of poultry meal (low or high ash content). All the diets were formulated on an equal lysine basis. The poultry meal replaced the lysine provided by fishmeal with inclusion rates of 2.9% and 5.8% for low ash and 3.1% and 6.2% for high ash poultry meal. The low ash and high ash poultry meal sources had ash concentrations of 9% and 13%, respectively.

Overall, d 0 to 15, pigs fed diets containing fishmeal or poultry meal had improved (P<0.05) F/G compared to pigs fed the control diet. Also, pigs fed low ash poultry meal had improved (P<0.05) F/G compared to pigs fed high ash poultry meal. Consistent with many previous trials, these results indicate that the addition of select menhaden fishmeal to diets improved growth performance in weanling pigs the first week and feed efficiency over a two-week period. The addition of low ash poultry meal resulted in improvements in feed efficiency, whereas high ash poultry meal did not. Based on these data, quality control specifications, such as ash content, need to be considered when using poultry meal as an animal protein replacement in diets for nursery pigs.

(Key Words: Fishmeal, Poultry Meal, Weanling Pigs)

Introduction

The use of complex nursery diets with highly digestible ingredients has increased the need for specialty protein products, such as select menhaden fishmeal. However, specialty protein sources, such as fishmeal, are relatively expensive. Therefore, other specialty protein sources that have the potential to reduce diet cost without decreasing performance must be evaluated. Recent trials conducted at Kansas State University have looked at the possibilities of using poultry meal in nursery diets as a replacement for readily used and higher priced fishmeal. Results have indicated that the use of poultry meal is not comparable in pig performance to fishmeal. However, due to the processing of poultry meal, several different quality sources are available. It is expected that pig performance would improve with the use of a higher quality poultry meal than used in prior experiments. Therefore, the objective of this study

[1]Appreciation is expressed to Tyson Foods for supplying the poultry meals.
[2]Food Animal Health and Management Center.

is to evaluate the effects of two different grades of poultry meal in nursery pig performance to determine potential use in early wean swine diets.

Procedures

A total of 350 pigs (initially 19.7 lb and 22 ± 2 d of age, PIC) was used in a 15-d growth assay. Pigs were blocked by weight and allotted to one of seven dietary treatments at weaning. There were ten replicates per treatment with five pigs per pen. Pigs were housed in an environmentally controlled nursery at the KSU Segregated Early Wean Facility. All pens (4 x 4 ft) contained one self-feeder and one nipple waterer to provide ad libitum access to feed and water.

The two different sources of poultry meal were analyzed for amino acids Ca and P before use in the diet formulation (Table 1). Pigs were fed one of seven dietary treatments, which included a control diet with no specialty protein products, or diets containing 2.5% or 5% fishmeal, or two different sources of poultry meal (low or high ash content). The poultry meal replaced the lysine provided by fishmeal with inclusion rates of 2.9% and 5.8% for low ash and 3.1% and 6.2% for high ash. All diets were corn-soybean meal based and included 10% edible grade spray-dried whey and were formulated to contain 1.45% total lysine, 0.90% Ca, and 0.76% P (Table 2). Average daily gain, ADFI, and feed efficiency (F/G) were determined by weighing pigs and measuring feed disappearance on d 7 and 15 of the trial or d 11 and 19 post weaning.

Data were analyzed as a randomized complete block design using the mixed procedure of SAS with pen as the experimental unit. Linear and quadratic comparisons were used to determine the effects of feeding increasing levels of fishmeal and both sources of poultry meal. Contrasts were made between the control and fishmeal, control and poultry meal, fishmeal versus poultry meal, and low ash versus high ash poultry meal.

Table 1. Chemical Analysis

Item, %	Low Ash Poultry Meal	High Ash Poultry Meal
CP	60.95	60.87
Ca	2.56	3.11
P	1.82	2.09
Lysine	4.20	3.95
Isoleucine	2.48	2.47
Leucine	4.57	4.36
Methionine	1.29	1.25
Met. and cys.	2.00	1.93
Threonine	2.41	2.28
Tryptophan	0.70	0.59
Valine	2.97	2.94

[a]Values represent the analysis of one sample of each ingredient.

Results and Discussion

From d 0 to 7, increasing fishmeal in the diet increased (linear, $P<0.05$) ADG. Increasing poultry meal (mean of both low and high sources) increased (quadratic, $P<0.05$) ADG with the greatest improvement at the low inclusion and then decreasing at the highest inclusion rate. Pigs fed the diet containing low ash poultry meal had improved ($P<0.05$) F/G compared to pigs fed the diet containing high ash poultry meal. Increasing the levels of fishmeal or poultry meal improved (quadratic, $P<0.05$) feed efficiency, with the greatest improvement at the lower inclusion rate for all sources.

From d 7 to 15, pigs fed diets containing low ash poultry meal tended to have improved ($P<0.10$) F/G compared to pigs fed diets containing high ash poultry meal.

Overall, d 0 to 15, pigs fed diets containing low ash poultry meal had improved ($P<0.05$) F/G compared to pigs fed diets con-

taining high ash poultry meal. Increasing the inclusion of fishmeal or poultry meal within the diet improved (linear, P<0.05) F/G.

Consistent with many previous trials, these results indicate that the addition of select menhaden fishmeal to diets improved growth performance in weanling pigs the first week and improved feed efficiency over a two-week period. The addition of low ash poultry meal resulted in improvements in feed efficiency, whereas high ash poultry meal did not. Based on these data, quality control specifications, such as ash content, need to be considered when using poultry meal as an animal protein replacement in diets for nursery pigs.

Table 2. Diet Composition (As-fed Basis)[a]

		Select Menhaden Fishmeal		Poultry meal 9% Ash[b]		Poultry meal 13% Ash[b]	
Item, %	Control	2.5%	5.0%	2.9%	5.8%	3.1%	6.2%
Corn	44.84	46.97	49.04	46.36	47.82	46.25	47.62
Soybean meal, 46.5%	37.27	33.10	28.94	33.10	28.95	33.09	28.95
Spray dried whey	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Soy oil	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Select menhaden fish meal	-	2.50	5.00	-	-	-	-
Low ash poultry meal	-	-	-	2.90	5.80	-	-
High ash poultry meal	-	-	-	-	-	3.10	6.18
Monocalcium phosphate, 21% P	1.45	1.20	0.95	1.30	1.18	1.25	1.08
Limestone	1.10	0.90	0.73	1.00	0.93	0.98	0.85
Antibiotic[c]	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Zinc oxide	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Lysine HCl	0.15	0.15	0.15	0.15	0.15	0.15	0.15
DL-methionine	0.14	0.13	0.13	0.14	0.13	0.13	0.13
L-threonine	0.05	0.05	0.06	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis, %							
Lysine	1.45	1.45	1.45	1.45	1.45	1.45	1.45
Isoleucine:lysine ratio	68	67	66	68	67	68	67
Leucine:lysine ratio	132	131	130	132	131	132	132
Methionine:lysine ratio	33	34	35	34	34	33	34
Met & cys:lysine ratio	60	60	60	60	60	60	60
Threonine:lysine ratio	65	65	65	65	65	65	65
Tryptophan:lysine ratio	20	19	19	19	19	19	19
Valine:lysine ratio	74	74	73	74	74	75	75
CP	22.35	22.17	21.98	22.31	22.27	22.42	22.48
Ca	0.90	0.90	0.90	0.90	0.91	0.90	0.90
P	0.76	0.76	0.76	0.76	0.76	0.76	0.76

[a]Pigs fed diets from d 4 to 19 after weaning.
[b]Poultry meal inclusion rates replaced of the lysine provided by fishmeal.
[c]Provided 50g/ton carbadox.

Table 3. Effects of Stabilized Poultry Meal on Growth Performance of Weanling Pigs[ab]

		Select Menhaden		Low Ash		High Ash				Contrast (P<)			
	Negative	Fishmeal		Poultry Meal[c]		Poultry Meal[c]				Con vs.	Con vs.	Fish vs.	Low vs.
	Control	2.5%	5.0%	2.9%	5.8%	3.1%	6.2%	SE	TRT[d]	Fish	Poultry	Poultry	High[e]
D 0 to 7													
ADG, lb[fi]	0.54	0.61	0.65	0.62	0.57	0.60	0.54	0.048	0.221	0.04	0.27	0.13	0.43
ADFI, lb	0.75	0.75	0.80	0.75	0.71	0.75	0.71	0.050	0.628	0.56	0.69	0.19	0.98
F/G[fghi]	1.38	1.22	1.24	1.22	1.25	1.29	1.33	0.052	0.018	0.01	0.01	0.21	0.04
D 7 to 15													
ADG, lb	1.08	1.12	1.10	1.10	1.11	1.07	1.15	0.059	0.877	0.57	0.54	0.99	0.81
ADFI, lb	1.41	1.43	1.42	1.39	1.40	1.46	1.47	0.066	0.884	0.85	0.75	0.89	0.16
F/G	1.33	1.29	1.30	1.27	1.28	1.36	1.28	0.041	0.270	0.38	0.40	0.87	0.09
D 0 to 15													
ADG, lb	0.83	0.88	0.89	0.87	0.86	0.85	0.87	0.040	0.800	0.11	0.28	0.40	0.80
ADFI, lb	1.10	1.11	1.13	1.09	1.08	1.13	1.12	0.050	0.955	0.69	0.97	0.60	0.32
F/G[fg]	1.34	1.27	1.27	1.25	1.27	1.32	1.29	0.026	0.014	0.01	0.01	0.43	0.01

[a]A total of 350 pigs initially 19.7 lb. and 21 ± 2 d of age with five pigs per pen and ten pens per treatment.
[b]Treatment diets fed from d 4 to 19 post weaning (d 0 to 15 of experiment).
[c]Poultry meal inclusion rates replaced the lysine provided by fishmeal.
[d]P-value represents overall treatment effect.
[e]Contrast between low and high ash poultry meal.
[f]Linear improvement with increasing fishmeal (P<0.05).
[g]Quadratic improvement with increasing fishmeal (P<0.06).
[h]Linear improvement with increasing poultry meal (P<0.05).
[i]Quadratic improvement with increasing poultry meal (P<0.05).

COMPARISION OF ANTIMICROBIAL ALTERNATIVES IN IRRADIATED DIETS FOR NURSERY PIGS

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Summary

Previous research at Kansas State University indicated that irradiation can effectively reduce the bacteria concentration in nursery diets. Therefore, we hypothesized that eliminating bacteria in the feed via irradiation would provide a model to determine the effectiveness of antimicrobial alternatives. In a 27-d growth assay, 330 weanling pigs (13.2 lb and 18 ± 2 d of age, PIC) were fed one of 9 experimental diets: 1) control diet with no antimicrobials, 2) irradiated control diet with no antimicrobials, and the irradiated control diet with added: 3) carbadox (50 g/ton), 4) Probios® (1.6% from d 0 to 14 and 0.8% from d 14 to 21), 5) BioSaf® (0.3%), 6) Biomate Yeast Plus® (0.1%), 7) Bio-Mos™ (0.3%), 8) Bio-Plus® 2B (0.05%), or 9) LactoSacc® (0.2%). BioSaf®, Biomate Yeast Plus®, and Lacto Sacc® are all concentrated forms of selected live yeast cells while Bio-Mos™ is a mannanoligosaccharide derived from yeast. Probios® is a form of lactic acid bacteria and Bio Plus® 2B contains two bacillus strains. All antimicrobials were added after diets were irradiated.

Neither irradiation nor feed additives in an irradiated diet improved growth performance compared to the nonirradiated control. Pigs fed the diet containing Probios had poorer ($P<0.05$) F/G compared to all other test diets except pigs fed the diet containing BioSaf. Pigs fed both the non-irradiated and irradiated control diets and Bio Plus 2B had improved ($P<0.05$) F/G compared to pigs fed diets containing Probios and BioSaf. These results indicate that whole diet irradiation or adding the feed additives to the irradiated diet did not improve growth performance. Eliminating the bacteria in the control diet by irradiation did not allow the impact of antimicrobial alternatives to be more easily measured.

(Key Words: Nursery Pig, Irradiation, Feed Additive)

Introduction

Studies evaluating pigs fed diets containing supplemental yeast, direct-fed microbials, and mannanoligosaccharides have had mixed results. Due to the mode of actions of yeast, direct-fed microbials, and mannanoligosaccharides on bacteria flora, we speculate that the total bacteria concentration and makeup of the feed might affect antimicrobial alternative performance. Currently, commercially available feed additives have not been evaluated in diets with reduced bacterial content. It has been shown that the process of irradiation is effective in reducing the bacteria content of whole diets. In past KSU Swine Day Reports, DeRouchey et al. (2001, 2002) reported irradiation of spray dried blood products im-

[1]Food Animal Health and Management Center.

proves (P<0.05) growth performance in nursery pigs; however, irradiation of the whole diet did not enhance performance. Therefore, evaluating antimicrobial alternatives in irradiated or bacteria reduced diets may provide a model to test their efficacy and could define uncertainties with the use of antimicrobial alternatives.

Procedures

A total of 360 weanling pigs (13.2 lb and 17 ± 2 d of age, PIC) was blocked by weight and allotted to one of nine dietary treatments. There were five pigs per pen and eight pens per treatment. Pigs were housed at the Kansas State University Segregated Early Weaning Facility. Each pen was 4 × 4 ft and contained one self-feeder and one nipple waterer to provide ad libitum access to feed and water.

All pigs were fed experimental diets immediately following weaning to d 27. There were nine experimental diets with a control diet with no antimicrobials, irradiated control diet with no antimicrobials, and the irradiated control diet with added; carbadox (50 g/ton), Probios® (1.6% from d 0 to 14 and 0.8% from d 14 to 21), BioSaf® (0.3%), Biomate Yeast Plus® (0.1%), Bio-Mos™ (0.3%), Bio-Plus® 2B (0.05%), or LactoSacc® (0.2%). BioSaf®, Biomate Yeast Plus®, and Lacto Sacc® are all concentrated forms of selected live yeast cells while Bio-Mos™ is a mannanoligosaccharide derived from yeast. Probios® is a form of lactic acid bacteria and Bio Plus® 2B contains two bacillus strains. All antimicrobials were added after the basal diet was irradiated. Diets were fed in meal form. Phase one diets (d 0 to 14) were formulated to contain 1.50% lysine, 0.90% Ca, and 0.54% available phosphorus. Phase two diets (d 14 to 27) were formulated to contain 1.45% lysine, 0.85% Ca, and 0.44% available phosphorus. In addition, diets did not contain growth-promoting levels of copper or zinc. All products were added at the manufacturers recommended inclusion rate. Samples of all diets were analyzed for bacteria concentration, and total plate count and coliform count were determined by diagnostic bacteriology testing (Table 2). Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) were determined by weighing pigs and measuring feed disappearance on d 7, 14, 21, and 27 post-weaning.

Data were analyzed as a randomized complete block design with pen as the experimental unit. Pigs were blocked based on weaning weight, and analysis of variance was performed using the Mixed procedure of SAS.

Results and Discussion

Irradiation was effective in reduction of the total plate and coliform count in the control diet (Table 2). From d 0 to 14 when pigs were fed phase one diets, treatment did not influence ADG and ADFI. Pigs fed the diet containing Bio Plus 2B tended to have improved (P<0.13) F/G compared to pigs fed diets containing carbadox or Probios. Pigs fed the diet containing Probios had a tendency for poorer (P<0.13) efficiency compared to pigs fed the control and irradiated control diet, and diets containing BioSaf, or Bio Plus 2B.

From d 14 to 27, there was no difference in growth parameters with the use of irradiation or the addition of feed additives.

Overall, (d 0 to 27) pigs fed the diet containing Probios had poorer (P<0.05) F/G compared to all other test diets except BioSaf. Furthermore, pigs fed either the non-irradiated and irradiated control diets or Bio Plus 2B had improved (P<0.05) F/G compared to pigs fed Probios and BioSaf.

Irradiation of the whole diet before adding antimicrobial alternatives was effective in reducing the bacteria concentrations of the diet. However, bacterial reduction by irradiation of the whole diet did not improve nursery pig

performance. When feeding irradiated diets, carbadox and antimicrobial alternatives did not improve growth performance in nursery pigs. Therefore, we speculate the bacterial concentration normally present in nursery diets is not a major factor when measuring the growth response of antimicrobial alternatives.

Table 1. Diet Composition (As-fed Basis)

Item, %	Phase I[a]	Phase II[b]
Corn	49.11	52.61
Soybean meal, 46.5% CP	25.74	33.36
Spray dried whey	15.00	7.50
Spray-dried animal plasma	5.00	-
Select menhaden fishmeal	-	2.50
Monocalcium phosphate, 21% P	1.40	1.15
Limestone	1.10	0.85
Salt	0.40	0.40
Vitamin premix	0.25	0.25
Trace mineral premix	0.15	0.15
Lysine HCl	0.15	0.15
DL-Methionine	0.10	0.08
Cornstarch or test ingredient	1.60	1.00
Total	100.00	100.00
Calculated Analysis		
Lysine, %	1.50	1.45
Isoleucine:lysine ratio, %	60	66
Leucine:lysine ratio, %	131	134
Methionine:lysine ratio, %	28	31
Met & Cys:lysine ratio, %	58	57
Threonine:lysine ratio, %	64	61
Tryptophan:lysine ratio, %	19	19
Valine:lysine ratio, %	74	75
ME, kcal/lb	1,491	1,493
CP, %	21.90	22.50
Ca, %	0.90	0.85
P, %	0.80	0.75
Available P, %	0.54	0.44
Lysine:calorie ratio, g/mcal	4.56	4.41

[a]Diets fed from d 0 to 14.
[b]Diets fed from d 14 to 27.
[c]Test ingredients replaced cornstarch from the control diet.

Table 2. Whole Diet Bacterial Count[a]

Phase One Diet, cfu/g	Total Plate Count	Coliform Count
Control / Non Irradiated	38,700	2,550
Control/ Irradiated	350	15
Carbadox	330	30
Probios	855,000	5
BioSaf	5,102,177	0
Yeast Plus	1,375,125	0
Bio-Mos	4,720	0
Bio-Plus 2B	575,000	0
Lacto Sacc	3,450	0

Phase Two Diet, cfu/g	Total Plate Count	Coliform Count
Control / Non Irradiated	3,000	490
Control/ Irradiated	40	0
Carbadox	480	0
Probios	330,000	0
BioSaf	70	0
Yeast Plus	3,865	2835
Bio-Mos	50	0
Bio-Plus 2B	800,000	0
Lacto Sacc	16,350	0

[a]Values represent the mean of two different samples analyzed.

Table 3. Effects of Irradiation and Antimicrobial Alternatives on Nursery Pig Performance[a]

		Irradiated	Feed Additives[b]								
Item	Control	Control	Carbadox	Probios	BioSaf	Yeast Plus	Bio-Mos	Bio-Plus 2B	LactoSacc	SE	TRT[c]
D 0 to 14[d]											
ADG, lb	0.38	0.38	0.39	0.36	0.35	0.37	0.39	0.39	0.35	0.037	0.901
ADFI, lb	0.47	0.47	0.52	0.49	0.44	0.47	0.49	0.47	0.45	0.041	0.716
F/G	1.24^{xy}	1.24^{xy}	1.35^{yz}	1.40^{z}	1.27^{xy}	1.30^{xyz}	1.31^{xyz}	1.21^{x}	1.29^{xyz}	0.060	0.064
D 14 to 27[e]											
ADG, lb	0.95	0.97	0.96	0.94	0.80	0.91	0.98	0.93	0.93	0.061	0.203
ADFI, lb	1.24	1.25	1.26	1.33	1.10	1.21	1.28	1.21	1.23	0.075	0.216
F/G	1.32	1.29	1.31	1.40	1.39	1.32	1.31	1.31	1.33	0.046	0.204
D 0 to 27											
ADG, lb	0.65	0.66	0.66	0.64	0.56	0.63	0.67	0.65	0.63	0.042	0.315
ADFI, lb	0.84	0.85	0.87	0.90	0.75	0.82	0.87	0.83	0.83	0.053	0.334
F/G	1.29^{f}	1.27^{f}	1.31^{fg}	1.40^{h}	1.35^{gh}	1.31^{fg}	1.30^{fg}	1.27^{f}	1.32^{fg}	0.037	0.003

[a]A total of 360 pigs initially 13.2 lb and 17 ± 2 d of age with five pigs per pen and eight replications per treatment.

[b]Inclusion rates are as follows; carbadox (50 g/ton), Probios® (1.6% from d 0 to 14 and 0.8% from d 14 to 21), BioSaf® (0.3%), Biomate Yeast Plus® (0.1%), Bio-Mos™ (0.3%), Bio-Plus® 2B (0.05%), or LactoSacc® (0.2%).0 to 14 fed phase one diet formulated to contain 1.50% lysine, 0.90% Ca, and 0.54% available P.

[c]P-value represents overall treatment effect.

[d]Inclusion rates are as follows; carbadox (50 g/ton), Probios® (1.6% from d 0 to 14 and 0.8% from d 14 to 21), BioSaf® (0.3%), Biomate Yeast Plus® (0.1%), Bio-Mos™(0.3%), Bio-Plus® 2B (0.05%), or LactoSacc® (0.2%).

[e]14 to 27 fed phase two diet formulated to contain 1.45% lysine, 0.85% Ca, and 0.44% available P.

[fgh]Means in the same row with different superscripts differ (P<0.05).

[xyz]Means in the same row with different superscripts differ (P<0.10).

COMPARISION OF ANTIMICROBIAL ALTERNATIVES IN DIETS FOR NURSERY PIGS

T.P. Keegan, J.M. DeRouchey, J.L Nelssen, M.D. Tokach, R.D. Goodband, S.S. Dritz[1], and C.W. Hasted

Summary

A total of 720 weanling pigs (12.8 lb and 18 ± 2 d of age, PIC) was used in two trials to determine the effectiveness of antimicrobial alternatives in diets for nursery pigs. Pigs were fed one of 8 experimental diets: 1) Control with no antibiotics or antimicrobial alternatives, 2) carbadox (50 g/ton), 3) Probios® (1.6% from d 0 to 14 and 0.8% from d 14 to 21), 4) BioSaf® (0.3%), 5) Biomate Yeast Plus® (0.1%), 6) Bio-Mos™(0.3%), 7) Bio-Plus® 2B (0.05%), or 8) LactoSacc® (0.2%). BioSaf®, Biomate® Yeast Plus®, and Lacto Sacc® are all concentrated forms of selected live yeast cells, while Bio-Mos™ is a mannanoligosaccharide derived from yeast. Probios® is a form of lactic acid bacteria and Bio Plus® 2B contains two bacillus strains.

Overall (d 0 to 27), pigs fed the diet containing carbadox had greater (P<0.05) ADG compared to pigs fed all other diets. Pigs fed the diet containing carbadox also had greater (P<0.05) ADFI compared to pigs fed BioSaf, Yeast Plus, Bio Mos, Bio Plus 2B and Lacto Sacc. Pigs fed the diet containing Bio Plus 2B had lower (P<0.05) ADFI compared to pigs fed the diet containing Probios. Pigs fed the diet containing Probios had the poorest (P<0.05) F/G compared pigs fed all other diets except the control diet. In addition, pigs fed the diet containing carbadox had improved (P<0.05) F/G compared to pigs fed the control diet or the diet containing Probios. In conclusion, the addition of carbadox – but not antimicrobial alternatives – in nursery pig diets resulted in a consistent improvement in growth performance over pigs fed the control diet. Although pigs fed antibiotic alternatives showed no improvement over carbadox, a numeric improvement in F/G for some products over pigs fed the control diet warrants further investigation.

(Key Words: Nursery Pig, Carbadox, Feed Additive)

Introduction

Antibiotics have been widely used within the swine industry to improve herd health and promote growth. However, due to recent concerns with the use of feed grade antibiotics in animal agriculture, antimicrobial alternatives are being further explored. Results of studies with pigs fed diets containing supplemental yeast, direct-fed microbials, and mannanoligosaccharides have been conflicting with some trials showing no improvement, whereas others show benefits in growth performance. Previous research at Kansas State University has evaluated the use of such products in bacteria reduced or irradiated diets. This experiment was designed to complement previous

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trials with the objective of evaluating several classes of antimicrobial alternatives on growth performance of nursery pigs within the same study.

Procedures

A total of 720 weanling pigs (12.8 lb and 17 ± 2 d of age, PIC) was blocked by weight and allotted to one of eight dietary treatments. The study was divided into two trials, the first beginning in September 2002, and the second starting in January 2003. The results were combined for statistical analysis for a total of 18 replications. The trials were conducted at the Kansas State University Segregated Early Weaning Facility. In each trial, there were five pigs per pen and nine pens per treatment. Each pen was 4 x 4 ft and contained one self-feeder and one nipple waterer to provide ad libitum access to feed and water.

All pigs were fed treatment diets from weaning to d 27 post-weaning. There were eight experimental diets with a control diet with no antimicrobials, or the control diet with added: carbadox (50 g/ton), Probios® (1.6% from d 0 to 14 and 0.8% from d 14 to 21), BioSaf® (0.3%), Biomate Yeast Plus® (0.1%), Bio-Mos™ (0.3%), Bio-Plus® 2B (0.05%), or LactoSacc® (0.2%). BioSaf®, Biomate Yeast Plus®, and Lacto Sacc® are all concentrated forms of selected live yeast cells, while Bio-Mos™ is a mannanoligosaccharide derived from yeast. Probios® is a form of lactic acid bacteria and Bio Plus® 2B contains two bacillus strains. All products were added at the manufacturers' recommended inclusion rates. Dietary treatments were fed in meal form. Phase one diets (d 0 to 14 post-weaning) were formulated to contain 1.50% lysine, 0.90% Ca, and 0.54% available phosphorus. Phase two diets (d 14 to 27) were formulated to contain 1.45% lysine, 0.85% Ca, and 0.44% available phosphorus. In addition, diets did not contain growth-promoting levels of copper or zinc. Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) were determined by weighing pigs and measuring feed disappearance on d 7, 14, 21, and 27 post weaning.

Data were analyzed as a randomized complete block design with pen as the experimental unit. Pigs were blocked based on weaning weight, and analysis of variance was performed using the Mixed procedure of SAS.

Results and Discussion

From d 0 to 14, pigs fed the diet containing carbadox had greater ($P<0.05$) ADG compared to pigs fed all other diets. Pigs fed the diet containing carbadox had improved ($P<0.05$) F/G compared to pigs fed the control diet or diets containing Probios or Bio-Mos. Also, pigs fed diets containing BioSaf, Yeast Plus, Bio-Plus 2B or Lacto Sacc had improved ($P<0.05$) F/G compared to pigs fed Probios.

From d 14 to 27, pigs fed the diets containing carbadox or Probios had greater ($P<0.05$) daily feed intake compared to pigs fed all other diets. Pigs fed the diet containing Bio Mos had improved ($P<0.05$) F/G compared to pigs fed the control diet with no antimicrobials or pigs fed the diet containing Probios. In addition, pigs fed diets containing carbadox, Yeast Plus, Bio Plus 2B or Lacto Sacc had improved ($P<0.05$) F/G compared to pigs fed the diet containing Probios.

Overall (d 0 to 27), pigs fed the diet containing carbadox had greater ($P<0.05$) ADG compared to pigs fed all other diets. Pigs fed the diet containing carbadox also had greater ($P<0.05$) ADFI compared to pigs fed diets containing BioSaf, Yeast Plus, Bio Mos, Bio Plus 2B or Lacto Sacc. Pigs fed the diet containing Probios had greater ($P<0.05$) ADFI than pigs fed the diet containing Bio-Plus 2B. Pigs fed the diet containing carbadox had improved ($P<0.05$) F/G compared to pigs fed the control diet or the diet containing Probios. In addition, pigs fed diets containing BioSaf,

Yeast Plus, Bio-Mos, Bio-Plus 2B or Lacto Sacc had improved (P<0.05) F/G compared pigs fed the diet containing Probios.

In conclusion, the addition of antimicrobial alternatives in nursery pig diets did not result in a consistent improvement in growth performance over pigs fed the control diet. However, pigs fed the diet containing carbadox had improved (P<0.05) ADG (10%) and F/G and tended to have numerically greater ADFI (6%) compared to pigs fed the control diet. Although pigs fed antibiotic alternatives showed no improvement over carbadox, numeric improvement in F/G for some products over pigs fed the control diet warrants further investigation.

Table 1. Diet Composition (As-fed Basis)

Item, %	Phase I[a]	Phase II[b]
Corn	49.11	52.61
Soybean meal, 46.5% CP	25.74	33.36
Spray dried whey	15.00	7.50
Spray-dried animal plasma	5.00	-
Select menhaden fish meal	-	2.50
Monocalcium phosphate, 21% P	1.40	1.15
Limestone	1.10	0.85
Salt	0.40	0.40
Vitamin premix	0.25	0.25
Trace mineral premix	0.15	0.15
Lysine HCl	0.15	0.15
DL-Methionine	0.10	0.08
Corn starch or test ingredient[c]	1.60	1.00
Total	100.00	100.00
Calculated Analysis		
Lysine, %	1.50	1.45
Isoleucine:lysine ratio, %	60	66
Leucine:lysine ratio, %	131	134
Methionine:lysine ratio, %	28	31
Met & Cys:lysine ratio, %	58	57
Threonine:lysine ratio, %	64	61
Tryptophan:lysine ratio, %	19	19
Valine:lysine ratio, %	74	75
ME, kcal/lb	1,491	1,493
CP, %	21.90	22.50
Ca, %	0.90	0.85
P, %	0.80	0.75
Available P, %	0.54	0.44
Lysine:calorie ratio, g/mcal	4.56	4.41

[a]Diets fed from d 0 to 14.
[b]Diets fed from d 14 to 27.
[c]Test ingredients replaced cornstarch.

Table 2. The Effects of Antimicrobial Alternatives on Nursery Pig Performance[a]

		Feed Additives[b]								
	Control	Carbadox	Probios	BioSaf	Yeast Plus	Bio-Mos	Bio-Plus 2B	LactoSacc	SE	TRT[c]
D 0 to 14[d]										
ADG, lb	0.38[e]	0.44[f]	0.35[e]	0.38[e]	0.38[e]	0.38[e]	0.39[e]	0.38[e]	0.021	0.018
ADFI, lb	0.47	0.49	0.46	0.46	0.46	0.46	0.46	0.45	0.021	0.782
F/G	1.26[ef]	1.14[g]	1.32[e]	1.23[fg]	1.23[fg]	1.26[ef]	1.20[fg]	1.21[fg]	0.044	0.005
D 14 to 27[h]										
ADG, lb	1.02	1.11	1.07	1.03	1.04	1.05	1.01	1.06	0.035	0.114
ADFI, lb	1.34[e]	1.43[f]	1.43[f]	1.33[e]	1.34[e]	1.31[e]	1.30[e]	1.34[e]	0.039	0.005
F/G	1.31[ef]	1.28[fg]	1.34[e]	1.30[efg]	1.29[fg]	1.26[g]	1.29[fg]	1.27[fg]	0.023	0.032
D 0 to 27										
ADG, lb	0.69[e]	0.76[f]	0.70[e]	0.69[e]	0.70[e]	0.70[e]	0.69[e]	0.70[e]	0.024	0.050
ADFI, lb	0.89[efg]	0.94[g]	0.93[fg]	0.88[ef]	0.89[ef]	0.87[ef]	0.86[e]	0.88[ef]	0.027	0.045
F/G	1.29[ef]	1.24[g]	1.33[e]	1.27[fg]	1.27[fg]	1.25[fg]	1.26[fg]	1.25[fg]	0.021	0.001

[a]A total of 720 pigs initially 12.8 lb and 18 ± 2 d of age with five pigs per pen and 18 replicates per treatment .

[b]Inclusion rates are as follows; carbadox (50 g/ton), Probios® (1.6% from d 0 to 14 and 0.8% from d 14 to 21), BioSaf® (0.3%), Bio-mate Yeast Plus® (0.1%), Bio-Mos™(0.3%), Bio-Plus® 2B (0.05%), or LactoSacc® (0.2%).

[c]P-value represents overall treatment effect.

[d]Phase one diets fed from d 0 to 14 and formulated to contain 1.50% lysine, 0.90% Ca, and 0.54% available P.

[efg]Means in the same row with different superscripts differ (P<0.05).

[h]Phase two diets fed from d 14 to 27 and formulated to contain 1.45% lysine, 0.85% Ca, and 0.44% available P.

Swine Day 2003

COMPARISION OF ANTIBIOTICS AND ANTIMICROBIAL ALTERNATIVES ON GROWTH PERFORMANCE OF WEANLING PIGS IN A COMMERCIAL ENVIRONMENT[1]

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Summary

A total of 320 weanling pigs (11.7 lb and 14 ± 3 d of age, PIC) was used to determine the effects of antibiotics and antimicrobial alternatives in diets for nursery pigs reared in a commercial environment. Pigs were fed one of 5 experimental diets: 1) control with no antimicrobials; 2) carbadox (50 g/ton); 3) Lacto-Sacc® (0.2%); 4) Bio-Plus® 2B (0.05%); or 5) Bio-Mos™(0.3%). Lacto Sacc® is a concentrated form of selected live yeast cells while Bio Plus® 2B contains two bacillus strains. Bio-Mos™ is a mannanoligosaccharide derived from yeast. Overall (d 0 to 31 post-weaning), pigs fed the control diet or diets containing Bio Mos had greater (P<0.05) ADG compared to pigs fed the diet containing Bio Plus 2B. Pigs fed the diet containing Bio Plus 2B had lower (P<0.05) daily feed intake compared to pigs fed the control diet or diets containing carbadox or Bio Mos with Lacto Sacc being intermediate in performance. There was no difference in feed efficiency among pigs fed various dietary treatments. In conclusion, in this commercial environment, the additions of carbadox or antimicrobial alternatives to the control diet were not effective in improving nursery pig performance.

(Key Words: Nursery Pig, Antibiotics, Feed Additive)

Introduction

The effectiveness of antibiotics in improving growth rate and feed efficiency in pigs has long been recognized. However, public concern has increased in regard to the use of subtherapeutic antibiotics. Research evaluating different antimicrobial alternatives has yielded mixed results. Data on the use of yeast, direct-fed microbials (probiotic), and mannanoligosaccharides have been conflicting with some trials showing little to no improvement and others showing benefits in growth performance. Recent trials conducted at a Kansas State University research facility have shown little improvement with the use of antimicrobial alternatives in a research setting. Studying the effects on pig performance with the addition of these products in a commercial environment might be more applicable in understanding potential industry use.

Procedures

A total of 320 weanling pigs (11.7 lb and 14 ± 2 d of age, PIC) was blocked by weight

[1]Appreciation is expressed to Eichman Brothers Farm (St. George, Kansas) for the use of pigs and facilities.
[2]Food Animal Health and Management Center.

and allotted to one of five dietary treatments. There were eight pigs per pen and eight pens per treatment. The trial was conducted in an environmentally controlled nursery facility on a commercial farm in northeast Kansas. Each pen was 4 × 6 ft and contained one self-feeder and two nipple waterers to provide ad libitum access to feed and water.

All pigs were fed treatment diets from weaning to d 31. There were five experimental diets with a control diet with no antimicrobials, or the control diet with added: carbadox (50 g/ton); LactoSacc® (0.2%); Bio-Plus® 2B (0.05%); or Bio-Mos™ (0.3%). Bio Plus® 2B contains two bacillus strains, Lacto Sacc® is a concentrated form of selected live yeast, and Bio-Mos™ is a mannanoligosaccharide derived from yeast. All products were added to meet the manufacturers' recommended inclusion rates. Dietary treatments were fed in meal form (Table 1). Segregated Early Wean (SEW) diets, which were fed based on a feed budget of one pound per pig, were formulated to contain 1.70% lysine, 0.81% Ca, and 0.60% available phosphorus. Transition diets were fed following completion of SEW diet to d 10 after weaning. The transition diets were formulated to contain 1.60% lysine, 0.92% Ca, and 0.59% available phosphorus. Phase II diets (d 10 to 31 post-weaning) were formulated to contain 1.51% lysine, 0.81% Ca, and 0.47% available phosphorus. These diets were formulated to match diets currently being fed at the commercial unit. Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) were determined by weighing pigs and measuring feed disappearance on d 10, 16, 23, and 31 post weaning.

Data were analyzed as a randomized complete block design with pen as the experimental unit. Pigs were blocked based on weaning weight, and analysis of variance was performed using the MIXED procedure of SAS.

Results and Discussion

From d 0 to 10, there was no difference in growth parameters between pigs fed the control diet or diets containing carbadox, Lacto Sacc, Bio Plus 2B, or Bio Mos.

From d 10 to 31, pigs fed the diet containing Bio Plus 2B had lower ($P<0.05$) ADG and ADFI compared to pigs fed the control diet and pigs fed diets containing carbadox or Bio Mos. There were no differences in feed efficiency.

Overall (d 0 to 31 post-weaning), pigs fed the control diet or Bio Mos had greater ($P<0.05$) ADG compared to pigs fed the diet containing Bio Plus 2B. Pigs fed the diet containing Bio Plus 2B had lower ($P<0.05$) feed intake compared to pigs fed all other diets except pigs fed the diet containing Lacto Sacc. There were no differences in feed efficiency across all treatments.

In conclusion, the addition of antimicrobial alternatives in nursery pig diets did not result in consistent improvement in growth performance compared to the control diet. In addition, the feed additive Bio Plus 2B, resulted in poorer performance compared to the control diet. In this commercial environment, the additions of carbadox or antimicrobial alternatives to the control diet were not effective in improving nursery pig performance. Further research needs to be done to evaluate the effects of different antibiotic sources in this commercial setting.

Table 1. Diet Composition (As-fed Basis)

Item, %	SEW[a]	Transition[b]	Phase II[c]
Corn	40.26	41.22	50.75
Soybean meal, 46.5%	12.09	21.56	27.68
Spray died whey	25.00	25.00	10.00
Spray-dried animal plasma	6.70	2.50	-
Select menhaden fishmeal	6.00	6.00	4.50
Lactose	5.00	-	-
Spray-dried blood meal	1.65	-	-
Soy oil	-	-	3.00
Test ingredient or starch[d]	1.00	1.00	1.00
Monocalcium phosphate, 21% P	0.50	0.75	1.00
Limestone	0.40	0.50	0.55
Zinc oxide	0.38	0.38	0.25
Salt	0.25	0.30	0.30
Vitamin premix	0.25	0.25	0.25
Lysine HCl	0.15	0.20	0.30
DL-methionine	0.15	0.13	0.15
Trace mineral premix	0.15	0.15	0.15
L-threonine	0.08	0.08	0.13
	100.00	100.00	100.00
Calculated Analysis			
Lysine, %	1.70	1.60	1.51
Isoleucine:lysine ratio, %	51	60	61
Leucine:lysine ratio, %	124	121	121
Methionine:lysine ratio, %	30	32	34
Met & cys:lysine ratio, %	56	57	58
Threonine:lysine ratio, %	66	66	64
Tryptophan:lysine ratio, %	18	18	17
Valine:lysine ratio, %	73	69	68
ME, kcal/lb	1,489	1,476	1,545
CP, %	22.59	22.28	21.22
Ca, %	0.81	0.92	0.81
P, %	0.78	0.83	0.75
Available P, %	0.60	0.59	0.47

[a]One pound fed per pig.
[b]Diets fed following SEW to d 10.
[c]Diets fed from d 10 to 31.
[d]Test ingredients replaced cornstarch at the following inclusion rates; carbadox (50 g/ton); LactoSacc® (0.2%); Bio-Plus® 2B (0.05%); or Bio-Mos™(0.3%).

Table 2. Effects of Antimicrobial Alternatives on Growth Performance in a Commercial Environment[a]

		Feed Additive[b]					
Item	Control	Carbadox	Lacto Sacc	Bio-Plus 2B	Bio Mos	SE	TRT[c]
D 0 to 10[d]							
ADG, lb	0.28	0.27	0.25	0.27	0.31	0.025	0.175
ADFI, lb	0.40	0.41	0.39	0.39	0.44	0.023	0.179
F/G	1.45	1.55	1.64	1.52	1.46	0.080	0.128
D 10 to 31[e]							
ADG, lb	0.90[g]	0.88[g]	0.87[fg]	0.81[f]	0.90[g]	0.032	0.045
ADFI, lb	1.19[g]	1.18[g]	1.16[fg]	1.09[f]	1.20[g]	0.036	0.035
F/G	1.32	1.35	1.32	1.35	1.33	0.022	0.606
D 0 to 31							
ADG, lb	0.70[g]	0.68[fg]	0.67[fg]	0.63[f]	0.71[g]	0.026	0.050
ADFI, lb	0.93[g]	0.93[g]	0.91[fg]	0.86[f]	0.95[g]	0.029	0.039
F/G	1.33	1.37	1.36	1.37	1.35	0.023	0.481

[a]A total of 320 pigs initially 11.7 lb. and 14 ± 3 d of age with eight pigs per pen and eight replications per treatment.

[b]Test ingredients replaced cornstarch at the following inclusion rates: carbadox (50 g/ton); LactoSacc® (0.2%); Bio-Plus® 2B (0.05%); or Bio-Mos™(0.3%).

[c]P-value represents overall treatment effect.

[d]One pound of SEW budgeted per pig with transition diet then fed until d 10.

[e]Phase two diets fed from d 10 to 31 and formulated to contain 1.51% lysine, 0.81% Ca, and 0.47% available P.

[fg]Means in the same row with different superscripts differ (P<0.05).

COMPARISION OF ANTIBIOTICS ON GROWTH PERFORMANCE OF WEANLING PIGS IN A COMMERICAL ENVIRONMENT[1]

T.P. Keegan, J.M. DeRouchey, J.L Nelssen, M.D. Tokach, R.D. Goodband, and S.S. Dritz[2]

Summary

A total of 320 weanling pigs (10.7 lb and 14 ± 3 d of age, PIC) was used to determine the effects of antibiotics and an antibiotic alternative on nursery pig performance. Pigs were fed one of 5 experimental diets: 1) control with no antimicrobials; 2) carbadox (50 g/ton); 3) Denagard/CTC (35 g/ton Denagard™, 400 g/ton Chlortetracycline); 4) Neo-Terramycin® (140 g/ton Neomycin Sulfate, 140 g/ton Oxytetracycline HCl); 5) Bio Mos (0.3%, mannanoligosaccharide). Overall (d 0 to 31 post-weaning), pigs fed the diet containing Denagard/CTC had the greatest (P<0.05) ADG and ADFI compared to pigs fed all other treatment diets. Pigs fed the diet containing Neo-Terramycin had greater (P<0.05) ADG compared to pigs fed the control diet or diets containing Carbadox or Bio Mos. In addition, pigs fed the diet containing Neo-Terramycin had greater (P<0.05) ADFI compared to pigs fed the control diet or the diet containing Bio Mos. In conclusion, the addition of carbadox and Bio Mos did not result in improved growth performance compared to pigs fed the control diet. However, improvements were seen in average daily gain and daily feed intake with the addition of Denagard/CTC and Neo-Terramycin. Commercial operations need to determine which feed additives improve nursery pig performance in their individual production systems.

(Key Words: Nursery Pig, Antibiotics, Feed Additive)

Introduction

The use of feed grade antibiotics in nursery pig diets has long been recognized as a method to improve growth performance and health. Due to recent concerns with the use of subtherapeutic antibiotics, research is being conducted on different options. Current research at Kansas State University has looked at viable options with the use of yeasts, direct fed microbials and mannanoligosaccharides. Results from these trials have not shown growth performance benefits to antibiotic alternatives. Also, these same trials found inconsistent responses to the continued use of certain antibiotics in a commercial setting. Therefore, the objective of this trial was to evaluate different antibiotics and antibiotic alternatives on nursery pig performance.

Procedures

A total of 320 weanling pigs (10.7 lb and 14 ± 3 d of age, PIC) were blocked by weight and allotted to one of five dietary treatments.

[1]Appreciation is expressed to Eichman Brothers Farm (St. George, Kansas) for the use of pigs and facilities.

[2]Food Animal Health and Management Center.

There were eight pigs per pen and eight pens per treatment. The trial was conducted in an environmentally controlled nursery facility on a commercial farm in northeast Kansas. Each pen was 4 x 6 ft and contained one self-feeder and two nipple waterers to provide ad libitum access to feed and water.

All pigs were fed treatment diets from weaning to d 31. There were five experimental diets, with a control diet with no antimicrobials, or the control diet with added: carbadox (50 g/ton); Denagard/CTC (35 g/ton Denagard™, 400 g/ton Chlortetracycline); Neo-Terramycin® (140 g/ton Neomycin Sulfate, 140 g/ton Oxytetracycline HCl); Bio Mos (0.3% mannanoligosaccharide). All products were added at the manufacturers' recommended inclusion rates. Dietary treatments were fed in meal form (Table 1). Segregated Early Wean (SEW) diets, which were fed based on a feed budget of one pound per pig, were formulated to contain 1.70% lysine, 0.81% Ca, and 0.60% available phosphorus. Transition diets were fed following completion of SEW diet until d 9 post-weaning. The transition diets were formulated to contain 1.60% lysine, 0.92% Ca, and 0.59% available phosphorus. Phase II diets (d 9 to 31 post-weaning) were formulated to contain 1.51% lysine, 0.81% Ca, and 0.47% available phosphorus. These diets were formulated to similar specifications that were fed at the commercial operation. Average daily gain (ADG), ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 9, 22, and 31 post-weaning.

Data were analyzed as a randomized complete block design with pen as the experimental unit. Pigs were blocked based on weaning weight, and analysis of variance was performed using the MIXED procedure of SAS.

Results and Discussion

From d 0 to 9, pigs fed the diet containing Denagard/CTC tended to have greater ($P<0.10$) ADG compared to pigs fed the control diet or pigs fed the diet containing Bio Mos.

From d 9 to 31 when pigs were fed phase two diets, pigs fed the diet containing Denagard/CTC had the greatest ($P<0.05$) ADG and ADFI compared to pigs fed all other diets. Also, pigs fed the diet containing Neo-Terramycin had greater ($P<0.05$) ADG and ADFI compared to pigs fed the control diet or diets containing carbadox or Bio Mos. No difference in feed efficiency was observed from d 9 to 31.

Overall (d 0 to 31 post-weaning), pigs fed the diet containing Denagard/CTC had the greatest ($P<0.05$) ADG and ADFI compared to pigs fed all other treatment diets. Pigs fed the diet containing Neo-Terramycin had greater ($P<0.05$) ADG compared to pigs fed the control diet or pigs fed diets containing carbadox or Bio Mos. In addition, pigs fed the diet containing Neo-Terramycin had greater ($P<0.05$) ADFI compared to pigs fed the control diet and pigs fed the diet containing Bio Mos. There was no difference in F/G between the dietary treatments.

As expected, no differences in pig weight variation were seen at the start of the trial due to allotment and randomization methods. However, pigs fed the diet containing Bio Mos tended to have greater ($P<0.05$) weight variation at trial completion (d 31) compared to pigs fed the control diet or diets containing Denagard/CTC or Neo-Terramycin.

In conclusion, similar to previous trials conducted at Kansas State University, the addition of a mannanoligosaccharide did not improve growth performance. Also, the use of Carbadox in this commercial operation did not improve growth performance, which agrees with previous research conducted in this facility. However, improvement in growth performance was seen in with the addition of Denagard/CTC and Neo-Terramycin. These data

confirm the importance of monitoring performance when using antibiotics or antibiotic alternatives in determining which additives are the most effective in individual operations.

Table 1. Diet Composition (As-fed Basis)

Item, %	SEW[a]	Transition[b]	Phase II[c]
Corn	40.26	41.22	50.75
Soybean meal, 46.5%	12.09	21.56	27.68
Spray died whey	25.00	25.00	10.00
Spray-dried animal plasma	6.70	2.50	-
Select menhaden fishmeal	6.00	6.00	4.50
Lactose	5.00	-	-
Spray-dried blood meal	1.65	-	-
Soy oil	-	-	3.00
Test ingredient or starch[d]	1.00	1.00	1.00
Monocalcium phosphate, 21% P	0.50	0.75	1.00
Limestone	0.40	0.50	0.55
Zinc oxide	0.38	0.38	0.25
Salt	0.25	0.30	0.30
Vitamin premix	0.25	0.25	0.25
Lysine HCl	0.15	0.20	0.30
DL-methionine	0.15	0.13	0.15
Trace mineral premix	0.15	0.15	0.15
L-threonine	0.08	0.08	0.13
	100.00	100.00	100.00
Calculated Analysis			
Lysine, %	1.70	1.60	1.51
Isoleucine:lysine ratio, %	51	60	61
Leucine:lysine ratio, %	124	121	121
Methionine:lysine ratio, %	30	32	34
Met & cys:lysine ratio, %	56	57	58
Threonine:lysine ratio, %	66	66	64
Tryptophan:lysine ratio, %	18	18	17
Valine:lysine ratio, %	73	69	68
ME, kcal/lb	1,489	1,476	1,545
CP, %	22.59	22.28	21.22
Ca, %	0.81	0.92	0.81
P, %	0.78	0.83	0.75
Available P, %	0.60	0.59	0.47

[a]One pound fed per pig. [b]Diets fed following SEW to d 9 post-weaning. [c]Diets fed from d 9 to 31 post-weaning. [d]Test ingredients replaced cornstarch at the following inclusion rates: carbadox (50 g/ton); Denagard/CTC (35 g/ton Denagard™, 400 g/ton Chlortetracycline); Neo-Terramycin® (140 g/ton Neomycin Sulfate, 140 g/ton Oxytetracycline HCl); Bio Mos (0.3% mannanoligosaccharide).

Table 2. Effects of Antibiotics and an Antimicrobial Alternative on Growth Performance of Weanling Pigs[a]

		Feed Additives[b]					
Item	Control	Carbadox	Denagard/ CTC	Neo-Terramycin	Bio Mos	SE	TRT[c]
D 0 to 9[d]							
ADG, lb	0.31[x]	0.35[xy]	0.36[y]	0.35[xy]	0.30[x]	0.024	0.070
ADFI, lb	0.40	0.45	0.46	0.42	0.41	0.025	0.110
F/G	1.32	1.31	1.30	1.23	1.35	0.060	0.317
D 9 to 31[e]							
ADG, lb	0.86[f]	0.87[f]	1.02[h]	0.95[g]	0.82[f]	0.031	0.001
ADFI, lb	1.17[f]	1.17[f]	1.38[h]	1.27[g]	1.11[f]	0.038	0.001
F/G	1.35	1.35	1.35	1.33	1.37	0.020	0.513
D 0 to 31							
ADG, lb	0.70[f]	0.71[f]	0.83[h]	0.77[g]	0.67[f]	0.025	0.001
ADFI, lb	0.95[f]	0.96[fg]	1.11[h]	1.01[g]	0.91[f]	0.032	0.001
F/G	1.35	1.34	1.34	1.32	1.36	0.019	0.196
CV, %							
D 0	0.069	0.069	0.070	0.071	0.072	0.002	0.265
D 31	0.127[y]	0.141[xy]	0.126[y]	0.117[y]	0.169[x]	0.021	0.120

[a]A total of 320 pigs initially 10.7 lb and 14 ± 3 d of age with eight pigs/ pen and eight pens/ treatment.

[b]Test ingredients replaced cornstarch at the following inclusion rates: carbadox (50 g/ton); Denagard/CTC (35 g/ton Denagard™, 400 g/ton Chlortetracycline); Neo-Terramycin® (140 g/ton Neomycin Sulfate, 140 g/ton Oxytetracycline HCl); Bio Mos (0.3% mannano-ligosaccharide).

[c]P-value represents overall treatment means.

[d]One pound of SEW budgeted per pig with transition diet then fed until d 9 post-weaning.

[e]From d 9 to 31 pigs fed phase two diet.

[fgh]Means in the same row with different superscripts differ (P<0.05).

[xy]Means in the same row with different superscripts differ (P<0.10).

Swine Day 2003

EFFECTS OF A PREBIOTIC, INULIN, AND A DIRECT FED MICROBIAL ON GROWTH PERFORMANCE OF WEANLING PIGS

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Summary

A 32-day growth study with a total of 252 weanling pigs (18 ± 3 d of age) was conducted to evaluate the effects of a prebiotic, Inulin (a fructooligosaccharide derivative of chicory), and a direct fed microbial (Lactobacillus strain) in diets for weanling pigs. Pigs were fed one of six experimental diets containing: 1) no antibiotic or prebiotic (negative control); 2) carbadox (50 g/ton, positive control); 3) direct fed microbial (DFM, 0.1%); 4) Inulin (0.5% and 0.2% of phase I and phase II diets, respectively); 5) carbadox plus DFM; or 6) carbadox plus Inulin.

Pigs fed carbadox improved (P<0.04) ADG from d 0 to 14, 14 to 32, and overall (0 to 32) compared to pigs fed diets without carbadox. Pigs fed diets containing carbadox increased (P<0.01) ADFI from d 0 to 14 and tended to have increased (P<0.06) ADFI overall compared to pigs fed diets without carbadox. No differences in ADG or ADFI were seen for pigs fed diets containing either Inulin or the DFM compared to pigs fed diets without Inulin or DFM. Pigs fed the DFM had poorer feed efficiency d 0 to 14 (P<0.03), 14 to 32 (P<0.01), and overall (P<0.01) compared to those fed diets without DFM. Also, there was a trend for pigs fed diets containing Inulin to have poorer feed efficiency (P<0.07) from d 14 to 32 and overall when compared to pigs fed diets without Inulin.

There were no additive responses for ADG or ADFI when Inulin or DFM were combined with carbadox. Pigs fed diets containing both the DFM and carbadox resulted in poorer feed efficiency (P<0.02) from d 14 to 32 and overall (0 to 32) than pigs fed diets without carbadox or DFM. Pigs fed the diet containing Inulin and carbadox had poorer feed efficiency from d 0 to 14 (P<0.04) compared to pigs fed diets without carbadox or Inulin. In summary, nursery diets containing either Inulin or the DFM did not enhance growth performance; however, carbadox improved ADG and ADFI.

(Key Words: Antibiotics, Antimicrobials, Weanling Pigs)

Introduction

Recent concerns with antibiotic resistance in humans and animals have led to increased research efforts to evaluate alternative products. Several direct fed microbial products and Lactobacillus strains are available that may improve the environment for gram positive bacteria in the intestinal lining and reduce the amount of gram negative bacteria found in the gut. It is believed that altering the intestinal bacteria may reduce the incidence of scours and increase nutrient digestibility and absorption due to improved intestinal health. In ad-

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dition, nondigestible oligosaccharides (an indigestible fiber source) have been shown to increase the number of lactic acid producing bacteria (gram positive) in the intestinal lining. Inulin, a derivative of chicory, is a fructooligosaccharide that may improve nursery pig performance through these methods. Research involving antibiotic alternatives has not been consistent in improving growth performance in nursery pigs. Therefore, the objective was to determine whether a DFM (Lactobacillus strain) or Inulin can influence weanling pig performance and be a suitable replacement for antibiotics.

Procedures

A total of 252 weaned pigs (PIC, initially 13.1 lb and 18 ± 3 d of age) were blocked by weight and gender in a 32-day growth study. They were randomly allotted to one of six dietary treatments in a randomized complete block design. Each pen contained six pigs (three barrows and three gilts), with seven replicates (pens) per treatment. Pigs were housed at the Kansas State University Swine Teaching and Research Center in an environmentally controlled nursery, with the temperature set at 90ºF at weaning and lowered 2º each week. All pens (4 x 5 ft) contained one stainless steel self-feeder and a nipple waterer to allow ad libitum access to feed and water.

Pigs were fed one of six dietary treatments including: 1) no antibiotic or prebiotic (negative control); 2) carbadox (50 g/ton, positive control); 3) Direct fed microbial (DFM, 0.1%); 4) Inulin (0.5% and 0.2% of phase I and phase II diets, respectively); 5) carbadox plus DFM; or 6) carbadox plus Inulin.

Experimental diets were corn-soybean meal-based and fed in meal form for 32 days post-weaning. Phase I (1.55% lysine) was fed from d 0 to 14 post-weaning, and Phase II (1.45% lysine) was fed from d 14 to 32 post-weaning (Table 1). Diets did not contain growth promoting levels of zinc oxide or copper sulfate. Pigs were weighed and feed disappearance was measured on d 0, 7, 14, 21, 28, and 32 to determine ADG, ADFI, and F/G. Data were analyzed as a randomized complete block design with pen as the experimental unit using the Mixed procedure of SAS.

Table 1. Diet Composition (As-fed)[a]

Ingredient	Phase I[b]	Phase II[c]
Corn	47.50	59.40
Soybean meal, 46.5% CP	29.00	35.10
Spray dried whey	15.00	0.00
Select menhaden fishmeal	3.75	0.00
Monocalcium phosphate, 21% P	1.20	1.85
Limestone	0.70	1.10
Salt	0.40	0.40
Lysine HCl	0.30	0.30
Vitamin premix	0.25	0.25
Trace mineral premix	0.15	0.15
DL-Methionine	0.15	0.15
L-Threonine	0.10	0.10
Corn starch[d]	1.50	1.20
TOTAL	100.00	100.00
Calculated values, %		
Lysine	1.55	1.45
Isoleucine:lysine ratio	60	62
Leucine:lysine ratio	120	129
Methionine:lysine ratio	33	34
Met & Cys:lysine ratio	57	59
Threonine:lysine ratio	63	63
Tryptophan:lysine ratio	18	18
Valine:lysine ratio	68	71
CP	21.7	21.4
ME, kcal/lb	1,485	1,483
Ca	0.91	0.90
P	0.81	0.80

[a]All diets fed in meal form.
[b]Fed to pigs from d 0 to 14 post-weaning.
[c]Fed to pigs from d 14 to 32 post-weaning.
[d]Carbadox (50 g/ton), DFM (0.1%), Inulin (0.5% Phase I, 0.2% Phase II), or a combination of carbadox and either DFM or Inulin replaced cornstarch to provide the additional dietary treatments.

Results and Discussion

No carbadox by DFM or carbadox by Inulin interactions were detected for ADG or ADFI, therefore the treatment main effects are presented in Table 2. However, some F/G interactions were observed and are presented in Table 3, with main effects of F/G in Table 2.

From d 0 to 14, pigs fed diets containing carbadox had greater ADG ($P<0.01$) and ADFI ($P<0.01$) compared to pigs diets without carbadox. Pigs fed diets with either the DFM or Inulin had similar ADG and ADFI compared to pigs fed diets without DFM or Inulin ($P>0.11$). Also, pigs fed diets containing the DFM had poorer F/G ($P<0.03$) compared to pigs fed diets without DFM. Pigs fed diets containing the combination of Inulin and carbadox had poorer feed efficiency than pigs fed diets without carbadox or Inulin which resulted in a carbadox by Inulin interaction ($P<0.05$).

From d 14 to 32, pigs fed diets containing carbadox had increased ADG ($P<0.04$) compared to pigs fed diets without carbadox. Pigs fed diets with either the DFM or Inulin had similar ADG and ADFI compared to pigs fed diets without DFM or Inulin ($P>0.31$). Also, pigs fed diets containing DFM had poorer feed efficiency ($P<0.01$) than those fed diets without DFM. Furthermore, pigs fed diets containing Inulin tended to have poorer feed efficiency ($P<0.07$) than pigs fed diets without Inulin.

Pigs fed diets containing the combination of DFM and carbadox had poorer feed efficiency compared to pigs fed diets without carbadox or DFM which resulted in a carbadox by DFM interaction ($P<0.01$).

For the overall treatment period (d 0 to 32), pigs fed diets containing carbadox had greater ADG ($P<0.01$) and tended to have greater ADFI ($P<0.06$) compared with pigs fed diets without carbadox. Pigs fed diets containing DFM or Inulin had similar ADG and ADFI compared with pigs fed diets without DFM or without Inulin ($P>0.16$). Pigs fed diets containing the DFM had poorer feed efficiency ($P<0.01$) and pigs fed the diet containing Inulin tended to have poorer feed efficiency ($P<0.06$) than pigs fed diets without DFM or without Inulin. There also was a carbadox by DFM interaction where pigs fed the combination of DFM and carbadox had poorer feed efficiency ($P<0.03$) than pigs fed diets without carbadox or DFM.

Agreeing with many previous trials, feeding nursery pigs diets containing carbadox resulted in improved growth performance. However, neither the DFM nor Inulin improved ADG, ADFI, or F/G in this study. There also were no additive affects of combining these products with carbadox. In conclusion, Inulin and DFM were not suitable replacements for antibiotics to improve growth performance in nursery pigs in this study.

Table 2. Effects of a DFM & Inulin on Growth Performance of Nursery Pigs[a]

	Carbadox		DFM[b]		Inulin			Probability (P<)				
Item	0	50g/ton	0	0.1%	0	0.5% & 0.2%[c]	SE	Carbadox	DFM	Inulin	Carbadox & DFM	Carbadox & Inulin
Replicates	21	21	14	14	14	14						
Day 0 to 14												
ADG, lb	0.41	0.47	0.46	0.42	0.43	0.45	0.022	0.01	0.11	0.43	0.97	0.44
ADFI, lb	0.50	0.56	0.54	0.52	0.51	0.55	0.024	0.01	0.66	0.19	0.63	0.71
Feed/Gain	1.22	1.20	1.17	1.25	1.20	1.22	0.036	0.76	0.03	0.61	0.69	0.05
Day 14 to 32												
ADG, lb	1.15	1.22	1.20	1.16	1.18	1.18	0.031	0.04	0.31	0.85	0.32	0.37
ADFI, lb	1.66	1.71	1.68	1.70	1.67	1.70	0.043	0.22	0.66	0.46	0.63	0.82
Feed/Gain	1.45	1.43	1.41	1.47	1.42	1.46	0.021	0.22	0.01	0.07	0.01	0.27
Day 0 to 32												
ADG, lb	0.83	0.89	0.87	0.84	0.86	0.86	0.023	0.01	0.16	0.85	0.66	0.49
ADFI, lb	1.15	1.21	1.18	1.18	1.16	1.20	0.031	0.06	0.85	0.30	0.83	0.76
Feed/Gain	1.41	1.38	1.36	1.43	1.38	1.41	0.017	0.14	0.01	0.06	0.03	0.89

[a]A total of 252 pigs initially 13.1 lbs and 18 ± 3 d of age.
[b]Lactobacillus strain.
[c]Inclusion rate of: Phase I = 0.5%; and Phase II = 0.2%.

Table 3. Interactive Effects of Pigs Fed the DFM or Inulin with Carbadox

Item	Control	Inulin	Carbadox	Carbadox & Inulin	Interaction (P<)
Day 0 to 14					
Feed/Gain	1.24	1.18	1.16	1.25	0.05

Item	Control	DFM	Carbadox	Carbadox & DFM	Interaction (P<)
Day 14 to 32					
Feed/Gain	1.39	1.51	1.42	1.43	0.01
Day 0 to 32					
Feed/Gain	1.35	1.46	1.37	1.39	0.03

MANNANOLIGOSACCHARIDES IN DIETS FOR NURSERY PIGS

J.D. Hancock, C.L. Jones, and C.W. Starkey

Summary

A total of 168 pigs (average initial BW of 13.2 lb and avg initial age of 21 d) was used in a 35-d experiment to determine the effects of mannanoligosaccharides on growth performance of nursery pigs fed diets without antibiotics. Treatments were: 1) a positive control with carbadox added at 50 g/ton of diet, 2) a negative control without antibiotic, 3) the negative control with mannanoligosaccharides from dried *Saccharomyces cerevisiae* fermentation solubles (Bio-Mos added at 0.2% of the diet), and 4) the negative control diet with mannanoligosaccharides from the cell walls of yeast (Safmannan added at 0.1% of the diet).

For d 0 to 7, ADG and F/G was no better (P>0.36) for pigs fed the diet with antibiotic than the other treatments. However, this lack of difference was the result of good growth performance among pigs fed the diets with mannanoligosaccharides vs the negative control (i.e., P<0.07 for ADG and P<0.02 for F/G). For d 0 to 21 and overall (d 0 to 35), ADG was greater (P<0.02) for pigs fed diets with antibiotic vs the other treatments and for pigs fed mannanoligosaccharides vs the negative control (P<0.04). However, there were no differences in ADG, ADFI, or F/G among pigs fed diets with the two different sources of mannanoligosaccharides (P>0.49). Analyses of fecal samples indicated no effect of any treatment on fecal concentrations of total coliforms and E. coli (P>0.54).

In conclusion, we did observe a positive effect of the mannanoligosaccharides on growth performance of weanling pigs that was intermediate to the nonmedicated and medicated control diets. Those effects were not associated with changes in coliform concentrations in the feces and were most likely caused by other physiological effects.

(Key Words: Antimicrobial, Nursery Pigs, Mannanoligosaccharides)

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) subtherapeutic use of antibiotics as non-specific growth promoters. A more recent thrust has been to identify naturally occurring compounds, such as certain fatty acids, peptides, and carbohydrate fractions that have biological activity of benefit to growing animals. One such group or class of compounds that now merits special interest are the mannanoligosaccharides. Thus, the experiment reported herein was designed to determine the effects of two commercially available sources of mannanoligosaccharides (fermentation solubles vs yeast cell walls) on growth performance in nursery pigs.

Procedures

A total of 168 pigs (average initial BW of 13.2 lb and 21 d of age) were used in a 35-d experiment to determine the effects of mannanoligosaccharides on growth performance of nursery pigs fed diets without antibiotics. The pigs were sorted by weight and allotted to

pens based on gender and ancestry. There were six pigs per pen and seven pens per treatment.

The diets (Table 1) were formulated to: 1.8% lysine, 0.9% Ca, and 0.8% P for d 0 to 7; 1.6% lysine, 0.8% Ca, and 0.7% P for d 7 to 21; and 1.4% lysine, 0.75% Ca, and 0.65% P for d 21 to 35. Treatments were: 1) a positive control with carbadox added at 50 g/ton of diet, 2) a negative control without antibiotic, 3) the negative control with mannanoligosaccharides from dried *Saccharomyces cerevisiae* fermentation solubles (Bio-Mos added at 0.2% of the diet), and 4) the negative control diet with mannanoligosaccharides from the cell walls of yeast (Safmannan added at 0.1% of the diet). The different inclusion amounts for the two products were to supply comparable amounts of total mannanoligosaccharides.

For d 0 to 7 and 7 to 21, the diets were steam conditioned for approximately 10 seconds at atmospheric pressure and temperatures of 140°F and 160°F, respectively. Pelleting was in a CPM Master Model HD1000 pellet mill equipped with a 1.25 inch thick die having holes with 5/32 inch diameter. For d 21 to 35, the diets were fed in meal form.

The pigs were housed in an environmentally controlled nursery room having 4 × 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, 7, 21, and 35 to allow calculation of ADG, ADFI, and F/G. Additionally, fecal samples were collected (by rectal massage) from half of the pens on d 38 and the remaining half on d 39. On each day, the samples were pooled within pen and transferred immediately to a microbiology lab for determination of counts for total coliforms and E. coli.

All data were analyzed (using the GLM procedure of SAS) as a completely randomized design with gender and initial pen weight as covariates. Means were separated with the orthogonal contrasts: 1) antibiotic vs all others, 2) negative control vs mannanoligosaccharides, and 3) mannanoligosaccharides from fermentation solubles vs those from yeast cell walls.

Results and Discussion

For d 0 to 7, ADG and F/G were no better ($P>0.36$) for pigs fed the diet with antibiotic vs the other treatments. However, this lack of difference was the result of good growth performance among pigs fed the diets with mannanoligosaccharides vs the negative control (i.e., $P<0.07$ for ADG and $P<0.02$ for F/G). For the two sources of mannanoligosaccharides, ADG was not different ($P>0.39$), but F/G was improved when the mannanoligosaccharides were from the yeast cell walls ($P<0.04$).

For d 0 to 21 and overall (d 0 to 35), ADG was greater ($P<0.02$) for pigs fed diets with antibiotic vs the other treatments and for pigs fed mannanoligosaccharides vs the negative control ($P<0.04$). Pigs fed the mannanoligosaccharides had better F/G than pigs fed the negative control ($P<0.002$). However, for d 0 to 21 and 0 to 35, there were no differences in ADG, ADFI, or F/G among pigs fed diets with the different sources of mannanoligosaccharides ($P>0.49$).

In addition to the data for growth performance, we collected fecal samples to evaluate changes in the intestinal environment. There was a trend ($P<0.09$) for greater pH of the feces in pigs fed diets with the mannanoligosaccharides vs the negative control, but this change in pH did not affect counts for total coliforms and E. coli ($P>0.65$). Indeed, analyses of the fecal samples indicated no effect of any treatment on fecal concentrations of total coliforms and E. coli ($P>0.54$). Thus, it ap-

pears that the positive effects of the antibiotic and mannanoligosaccharides on growth performance were not associated with changes in the gut microflora we evaluated.

In conclusion, we did observe a positive effect of the mannanoligosaccharides on growth performance of weanling pigs that was intermediate to the nonmedicated and medicated control diets. Those effects were not associated with changes in coliform concentrations in the feces and were most likely caused by other physiological effects.

Table 1. Composition of Diets

Item	d 0 to 7	d 7 to 21	d 21 to 35
Ingredient, %			
Corn	38.95	49.44	57.93
Soybean meal	23.84	27.71	33.42
Edible grade whey	20.00	10.00	-
Spray-dried animal plasma	5.00	2.00	-
Spray-dried wheat gluten	5.00	-	-
Fishmeal	2.00	5.00	-
Soybean oil	2.00	3.50	5.00
Lysine HCl	0.38	0.21	0.31
DL-methionine	0.12	0.10	0.12
Threonine	0.07	0.07	0.11
Limestone	1.00	0.73	1.15
Monocalcium phosphate	1.06	0.53	1.22
Salt	0.20	0.30	0.35
Vitamin premix	0.25	0.25	0.25
Mineral premix	0.15	0.15	0.15
Antibiotic/mannans[a]	-	-	-
Calculated composition			
CP, %	26.3	23.4	21.1
Total lysine, %	1.80	1.60	1.40
Ca, %	0.90	0.80	0.75
Total P, %	0.80	0.70	0.65
ME, kcal/lb	1,539	1,584	1,604

[a]Provided 50 g of carbadox/ton of feed for the diets with antibiotic or 0.2% Bio-Mos or 0.1% Safmannan for the diets with mannanoligosaccharides.

Table 2. Effects of Mannanoligosaccharides on Growth Performance of Nursery Pigs[a]

						Contrasts[b]		
Item	Antibiotic	None	Bio-Mos	Saf-mannan	SE	Antibiotic vs others	None vs mannans	Bio-Mos vs Safmannan
d 0 to 7								
ADG, lb	0.54	0.45	0.51	0.55	0.03	–[c]	0.07	–
ADFI, lb	0.48	0.43	0.46	0.45	0.02	–	–	–
F/G	0.89	0.96	0.90	0.82	0.10	–	0.02	0.04
d 0 to 21								
ADG, lb	0.73	0.60	0.68	0.66	0.03	0.02	0.04	–
ADFI, lb	0.82	0.73	0.78	0.76	0.03	0.04	–	–
F/G	1.12	1.22	1.15	1.15	0.03	0.05	0.002	–
Overall (d 0 to 35)								
ADG, lb	1.01	0.87	0.94	0.94	0.02	0.002	0.04	–
ADFI, lb	1.33	1.24	1.24	1.23	0.03	0.02	–	–
F/G	1.32	1.43	1.32	1.31	0.02	0.11	0.001	–
Fecal analyses								
pH	6.00	5.87	6.00	6.01	0.06	–	0.09	–
Coliforms, $\log_{10}$	5.53	5.65	6.04	5.77	0.45	–	–	–
E. coli, $\log_{10}$	5.21	5.43	5.70	5.58	0.49	–	–	–

[a]A total of 168 pigs (six pigs per pen and seven pens per treatment) with an average initial BW of 13.2lb and an average initial age of 21 d.
[b]Contrasts were: 1) antibiotic vs all others, 2) negative control vs mannanoligosaccharides, and 3) mannanoligosaccharides from fermentation solubles (Bio-Mos) vs yeast cell walls (Safmannan).
[c]Dashes indicate P=0.15 or greater.

EFFECTS OF A HEAT-STABLE YEAST PRODUCT AND ANTIBIOTICS IN DIETS FOR NURSERY PIGS

J.D. Hancock, C.L. Jones, and C.W. Starkey

Summary

A total of 192 pigs (average initial BW of 15 lb and 21 d of age) were used in a 35-d experiment to determine the effects of a heat-stable yeast product on growth performance of nursery pigs fed diets without and with antibiotics. Treatment diets were formulated to: 1.7% lysine for d 0 to 7, 1.5% lysine for d 7 to 21, and 1.3% lysine for d 21 to 35. The treatments were arranged as a 2 × 2 factorial, with main effects of antibiotics (without and with carbadox at 50 g/ton) and yeast (without and with 0.2% Biosaf). All diets had 3,000 ppm total Zn for d 0 to 7 and 250 ppm total Cu for d 7 to 35. For d 0 to 7 and 7 to 21, the diets were steam conditioned for approximately 10 seconds at atmospheric pressure and temperatures of 140°F and 160°F, respectively. For d 21 to 35, the diets were fed in meal form.

The antibiotic improved efficiency of gain for d 0 to 7 and 0 to 21 ($P<0.04$). Rate of gain was greater ($P<0.01$) in pigs fed the antibiotic for d 0 to 21 and overall (d 0 to 35). However, there was no effect of yeast addition on growth performance ($P>0.15$) and there were no interactions among antibiotic and yeast addition in any phase of the experiment ($P>0.08$). In conclusion, the antibiotic (carbadox) was effective as a non-specific growth promoter, but the yeast product had minimal effect.

(Key Words: Nursery, Antibiotic, 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) subtheraputic use of antibiotics as non-specific growth promoters. In a previous experiment (Maloney et al., 1998), we demonstrated positive effects (improved ADG and gain/feed) in nursery pigs fed diets with antibiotics and a heat-stable yeast product (Biosaf) used in combination. Our results were encouraging as far as demonstrating improved growth performance in weanling pigs, but the experiment did not address the need to identify a direct-fed microbial that could be used to replace antibiotics. Thus, the experiment reported herein was designed to determine the effects of a heat-stable yeast product on nursery pigs fed diets without and with antibiotics.

Procedures

A total of 192 pigs (average initial BW of 15 lb and 21 d of age) were used in a 35-d experiment to determine the effects of a heat-stable yeast product on growth performance of nursery pigs fed diets without and with antibiotics. 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.

Treatment diets (Table 1) were formulated to: 1.7% lysine, 0.9% Ca, and 0.8% P for d 0

to 7; 1.5% lysine, 0.8% Ca, and 0.7% P for d 7 to 21; and 1.3% lysine, 0.75% Ca, and 0.65% P for d 21 to 35. The treatments were arranged as a 2 × 2 factorial with main effects of antibiotics (without and with carbadox at 50 g/ton) and yeast (without and with 0.2% Biosaf). All diets had 3,000 ppm total Zn for d 0 to 7 and 250 ppm total Cu for d 7 to 35.

For d 0 to 7 and 7 to 21, the diets were steam conditioned for approximately 10 seconds at atmospheric pressure and temperatures of 140°F and 160°F, respectively. In previous experiments, we found that the yeast product endured pelleting temperatures of 158 to 176°F with negligible loss of colony-forming units. Thus, the temperatures used in the present experiment were deemed to be sufficiently low to killing the yeast cells. Pelleting was in a CPM Master Model HD1000 pellet mill equipped with a 1.25 inch × 5/32 inch diameter holes. For d 21 to 35, the diets were fed in meal form.

The pigs were housed in an environmentally controlled nursery room having 4 ×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, 7, 21, and 35 to allow calculation of ADG, ADFI, and feed/gain.

All data were analyzed as a randomized complete block design using the GLM procedure of SAS. Means separation was that appropriate for a 2 × 2 factorial with the main effects of antibiotic treatment and incorporation of yeast into the diets.

Results and Discussion

The antibiotic improved efficiency of gain for d 0 to 7 and 0 to 21 ($P<0.04$). Rate of gain was greater ($P<0.01$) in pigs fed the antibiotic for d 0 to 21 and overall (d 0 to 35). However, there was no affect of yeast addition on growth performance ($P>0.15$) and there were no interactions among antibiotic and yeast addition in any phase of the experiment ($P>0.08$). In conclusion, the antibiotic (carbadox) was effective as a non-specific growth promoter, but the yeast product had minimal effect.

Table 1. Composition of Diets

Ingredient, %	d 0 to 7	d 7 to 21	d 21 to 35
Corn	30.52	44.01	60.90
Soybean meal	23.07	27.37	31.34
Edible grade whey	20.00	20.00	-
Lactose	10.00	-	-
Spray-dried animal plasma	4.00	-	-
Spray-dried wheat gluten	5.00	-	-
Spray-dried blood cells	1.00	2.00	-
Soybean oil	2.00	3.00	4.00
Lysine HCl	0.43	0.30	0.29
DL-methionine	0.17	0.23	0.10
Threonine	0.11	0.15	0.10
Tryptophan	0.01	0.01	-
Limestone	1.06	0.96	1.15
Monocalcium phosphate	1.64	1.18	1.28
Salt	0.20	0.30	0.35
Vitamin premix	0.25	0.25	0.25
Mineral premix	0.15	0.15	0.15
Zinc oxide[a]	0.39	-	-
Copper sulfate[b]	-	0.09	0.09
Antibiotic/yeast[c]	-	-	-
Calculated composition			
CP, %	24.12	21.19	20.05
Total lysine, %	1.70	1.50	1.30
Ca, %	0.90	0.80	0.75
Total P, %	0.80	0.70	0.65
ME, kcal/lb	1,519	1,542	1,574

[a]Total Zn concentration for d 0 to 7 was 3,000 ppm.
[b]Total Cu concentration for d 7 to 35 was 250 ppm.
[c]Provided 50 g/ton carbadox for d 0 to 35 in the diets with antibiotic and 0.02% Biosaf for the diets with yeast.

Table 2. Effects of Antibiotics and a Heat-Stable Yeast Product on Growth Performance of Nursery Pigs[a]

	W/O antibiotic		With antibiotic			Contrasts[b]		
Item	W/O yeast	With yeast	W/O yeast	With yeast	SE	Antibiotic	Yeast	AB × yeast
d 0 to 7								
ADG, lb	0.71	0.73	0.75	0.76	0.03	–[c]	–	–
ADFI, lb	0.63	0.70	0.65	0.65	0.02	–	0.15	0.18
Feed/gain	0.89	0.96	0.87	0.86	0.04	0.04	–	0.11
d 0 to 21								
ADG, lb	0.93	0.92	1.00	1.02	0.02	0.002	–	–
ADFI, lb	1.04	1.08	1.10	1.08	0.03	–	–	–
Feed/gain	1.12	1.17	1.10	1.06	0.04	0.02	–	0.08
Overall (d 0 to 35)								
ADG, lb	1.14	1.14	1.17	1.20	0.02	0.01	–	–
ADFI, lb	1.50	1.53	1.55	1.57	0.02	0.06	–	–
Feed/gain	1.32	1.43	1.32	1.31	0.03	–	–	–

[a]A total of 192 pigs (six pigs/pen and eight pens/treatment) with an average initial BW of 15 lb and an average initial age of 21 d.
[b]Contrasts were: 1) no antibiotic vs antibiotic; 2) no yeast vs yeast; and 3) no antibiotic vs antibiotic × no yeast vs yeast.
[c]Dashes indicate $P=0.15$ or greater.

EFFECTS OF BIOPLUS 2B AND LEVUCELL SB ON WEANLING PIG GROWTH PERFORMANCE AND FECAL SHEDDING IN RESPONSE TO ORAL CHALLENGE WITH *SALMONELLA* SEROVAR TYPHIMURIUM

M.R. Barker, S.S. Dritz[1], J.C. Nietfeld[2], and J.E. Minton

Summary

Eighty-five pigs (initially 12.9 lb and 15 ±1 d of age) were used in two 28-d trials to determine the effects of the probiotics BioPlus 2B (a bacillus-based product from Chr. Hansen BioSystems), a source of *Bacillus subtilis* and *Bacillus licheniformis*, and Levucell SB (an active dry yeast product from Lallemand Animal Nutrition), a yeast (*Saccharomyces cerevisiae*) product that is a source of mannanoligosaccharides on growth and performance of *Salmonella enterica* serovar Typhimurium shedding in a young growing pig model.

Pigs were fed one of five dietary treatments: 1) A control diet containing no probiotics or antibiotics; 2) the control diet with carbadox (50 g/ton); 3) the control diet with BioPlus 2B (0.05% of the diet); 4) the control diet with Levucell SB (100 g/ton); 5) the control diet with Bioplus 2B (0.05% of the diet) and Levucell SB (100 g/ton). Diets did not contain growth promoting levels of zinc oxide or copper sulfate.

Significant differences in the two trials were seen, with the second trial having 0.1 lb/d greater growth and .18 lb/d greater feed intake than the first trial. In trial 1, pigs fed the control diet and Bioplus 2B had greater gains and feed intakes ($P<0.05$ and $P<0.02$ respectively) than those fed carbadox. In trial two, pigs fed carbadox had better performance than those fed the control and combination diets, with the BioPlus 2B and Levucell SB treatments having intermediate growth and feed intake. Fecal shedding rates of *salmonella* were not different ($P>0.10$) between diets. Results indicate that within an environment where enteric disease may be active, BioPlus 2B and Levucell SB may provide growth enhancement over a diet devoid of antimicrobials.

(Key Words: Weanling Pigs, Disease Challenge, *Salmonella,* BioPlus 2B, and *Saccharomyces cerevisiae*)

Introduction

With greater consumer concerns over antibiotic resistance, there has been increased pressure to remove and find alternatives to antibiotics in livestock diets Alternatives to antimicrobials that may hold promise include probiotic feed additives. Supplementation of swine diets with probiotics to alter the intestinal microbial population and to promote gut health has shown variable responses in growth. Possible reasons for variation among trials may be due to various levels and species of enteric organisms within production sys-

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tems. Weanling pigs were fed the probiotics Bioplus 2B, a bacillus-based product, and Levucell SB, an active yeast culture, in order to determine the growth responses and bacterial shedding rates in the presence of an orally administered enteric pathogenic challenge.

Materials and Methods

The Kansas State University Institutional Animal Care and Use Committee approved the experimental protocol used in this study. Eighty-five weanling pigs (initially 12.9 lb) were blocked by initial weight and allotted to one of five dietary treatments in two 28 d trials. Two pigs were assigned to a pen, with a total of eight or nine replicates per treatment. All pigs were housed in two environmentally controlled rooms. One feeder and one nipple-waterer were provided in each pen to allow ad libitum access to feed and water. All pigs were fed a common diet for the first 7 d after weaning. The pigs were switched to the experimental dietary treatments for 14 d before inoculation. The basal diet contained no added antimicrobials, while the positive control diet contained carbadox (50 g/ton). The three test diets contained a bacillus-based product (BioPlus 2B, Chr. Hansen BioSystems; 0.05% of the diet), an active dry yeast product (Levucell SB, Lallemand Animal Nutrition; 100 g/ton), and a combination of the two products. The experimental diets were fed in meal form (Table 1).

Prior to challenge, fecal samples were taken to insure that all animals were not shedding salmonellae organisms. On d 14, pigs were inoculated with *Salmonella enterica* serovar Typhimurium (2.36×10^6 and 1.22×10^6 CFU in trials 1 and 2, respectively). This dose was used to closely mimic a chronic, but containable gut pathogen load. Rectal temperatures and feed intakes were determined daily for the first week after inoculation. Pigs were weighed and ADFI, ADG, and F/G were determined on days 0, 7, 14, 21, and 28 of the experimental period. Fecal samples were collected on d 21 and 28 days to be cultured for semi-quantitative counts of salmonellae.

Table 1. Diet Composition[ab] (As-fed)

Ingredients	Control
Corn	50.74
Soybean meal	27.94
Spray dried whey	10.00
Select menhaden fishmeal	4.50
Soy oil	3.00
Monocalcium phosphate, 21% P	1.20
Limestone	0.68
Salt	0.35
Vitamin premix	0.25
Trace mineral premix	0.15
Lysine HCl	0.15
DL-Methionine	0.05
Cornstarch[b]	1.00
Total	100.00%
Calculated analysis	
Lysine, %	1.39%
ME, kcal/kg	3388
Calcium, %	0.90
Phosphorous, %	0.79

[a]Diets did not contain growth promoting levels of zinc oxide or copper sulfate.
[b]Test ingredients, carbadox (50 g/ton), BioPlus 2B (0.05% of the diet), and Levucell SB (100 g/ton) replaced cornstarch to provide the additional dietary treatment.

A semi-quantitative method for evaluating *Salmonella* shedding was developed for the experiment. *Salmonella* growth was classified into one of four categories; 1) confluent growth over the entire agar plate (score 3); 2) any number of wells with growth on the agar plate (score 2); 3) only growth that was obtained on enrichment (score 1); 4) or no growth detected (score 0). The shedding and colonization scores were analyzed using the non-parametric Kruskal-Wallis Test. On d 27 and 28 of the study pigs were euthanized and fecal samples from the colon were collected and tested for the presence of culturable *Salmonella*.

Data were analyzed in a randomized complete block design replicated over time using the Mixed model procedures of SAS. All means presented are least-square means.

Results and Discussion

Both trials are reported separately due to significant trial differences (P<0.05) for all variables except feed efficiency, and diet x trial interactions (P<0.05) for all variables except feed efficiency and daily rectal temperatures.

Growth Performance

Trial 1. No differences in ADG or ADFI were seen in the two weeks prior to challenge (Figure 1, left panels). In the two weeks following challenge the pigs fed the control diet or Bioplus 2B diet had greater ADG than pigs fed the antibiotic or Levucell diets (P<0.01). Pigs fed the diet containing the combination of Bioplus 2B and Levucell had decreased ADG compared to the control pigs (P>0.03), but not with the pigs fed the diet containing Levucell (P<0.06). Greater feed intakes were observed for the pigs fed the control diet and diet containing Bioplus 2B compared to the pigs fed carbadox, Levucell, or the combination treatment (P<0.03). For the overall trial, pigs fed the control and Bioplus 2B diets had greater ADG and ADFI than the pigs fed carbadox, with the pigs fed Levucell and the combination being intermediate in ADG (P<0.03) and ADFI (P<0.02). No differences were observed in feed efficiency.

Growth performance in the first trial was surprising in that pigs fed carbadox gained more slowly than control pigs. No obvious reasons for this effect could be identified. Initially it was hypothesized that the carbadox and control diets may have been accidentally switched at the feed mill. However, upon analysis of the diets at a commercial laboratory, it was determined that the carbadox diet did indeed contain the antimicrobial at the appropriate level and the negative control contained no antimicrobials. At present we don't have an explanation for the failure of carbadox to improve growth performance compared with control pigs. Pigs fed the Bioplus 2B diets performed similarly to the pigs fed the control diet, with the Levucell and combination fed pigs performing intermediate in response to enteric challenge. The combination of the two probiotics showed no additive benefit before or after enteric challenge.

Trial 2. Pigs fed carbadox had greater ADG (P<0.05) and ADFI (P<0.04) when compared to the pigs fed the control, Bioplus 2B, and combination diets prior to challenge (Figure 1, right panels). Pigs fed the diet containing Levucell had intermediate ADG (P<0.07) and ADFI (P<0.04) in comparison to carbadox and control, Bioplus 2B, or the combination diets. In the 2 weeks following bacterial challenge pigs fed the diet containing carbadox had greater ADG than pigs fed the control diet (P<0.01), with the Bioplus 2B, Levucell, and combination fed pigs intermediate in growth (P<0.40). Following challenge, carbadox-fed pigs had greater feed intakes than the control or combination-fed pigs (P< 0.01). The Bioplus 2B and Levucell-fed pigs were also higher (P<0.05) in feed intake than the control. Overall, carbadox-fed pigs had greater growth than the control (P<0.01) and combination diets (P<0.05), with pigs fed Bioplus 2B (P<0.09) and Levucell having intermediate performance (P<0.12). Overall in trial 2, the carbadox fed pigs had greater (P<0.02) feed intake than the control or combination pigs. The Bioplus 2B and Levucell fed pigs were intermediate in intake. There were no differences in feed efficiency.

The increase in feed intake and growth when feeding carbadox both before and after enteric challenge is consistent with several previous research trials in our laboratory. Bioplus 2B and Levucell SB pigs were intermediate in growth and feed intake in comparison to the control and carbadox-treated pigs.

Although neither Levucell nor Bioplus 2B treatments matched carbadox in growth response, both did numerically, though not significantly, better than the control fed pigs. The combination of Bioplus 2B and Levucell showed no additive benefit before or after challenge.

Fecal Salmonella Shedding Scores

Fecal *Salmonella* were cultured and measured 7 and 14 d following challenge with *Salmonella* serotype Typhimurium (corresponds to d 21 and 28 of trials). Pen shedding scores did not differ between treatments and were low and variable between days and trials, generally ranging between scores of 0 and 1 among treatments.

Initially it was hypothesized that fecal scores would be lowest for carbadox treated pigs, with the Bioplus 2B and Levucell being intermediate. Our hypothesis was based on the ability of antimicrobials to inhibit the growth of pathogenic organisms within the gut. Throughout both trials, fecal scores were typically low for presence of *Salmonella* for days 21 and 28 of the trials. No obvious treatment differences were observed.

Summary

Growth performance and feed intake were not typical in trial 1 for the control and antibiotic treatments in comparison to previous research conducted within our laboratory. Reasons for the underperformance of the antimicrobial regimen are uncertain in the presence of an enteric pathogen. However, trial 2 showed all treatments having improved performance over the control diet. Trial 2 also showed the expected growth enhancement properties of carbadox in the presence of enteric disease. Although not significant, Bioplus 2B and Levucell showed improvement over the control with about a 10% improvement in growth and 7% improvement in feed intake. The combination treatment showed only a 7% improvement in growth over the control in trial 2. These, diets containing Bioplus 2B or Levucell SB in a production environment may provide improved growth enhancement over diets with no antimicrobials in the presence of an enteric pathogen.

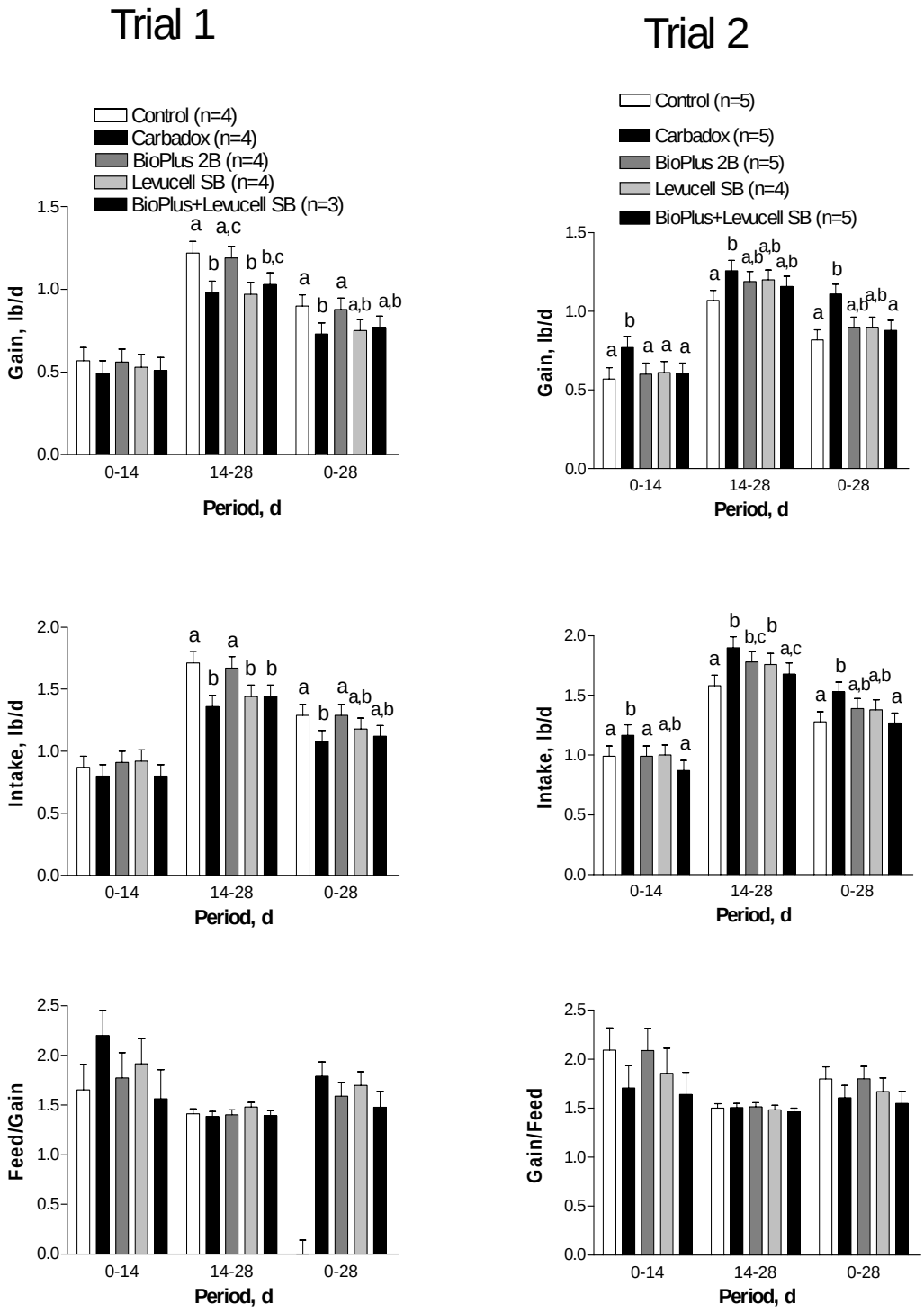

Figure 1. Effect of BioPlus 2B and Levucell SB on growth performance of weaned pigs prior to and after oral challenge with 106 *Salmonella* Serovar Typhimurium on d 14 in both trials. The number of pens per treatment is given in parenthesis in the figure legends. Within period bars with different superscripts differ (P< 0.05).

Swine Day 2003

CORN PARTICLE SIZE AND PELLETING INFLUENCE ON GROWTH PERFORMANCE, FECAL SHEDDING, AND LYMPH NODE INFECTION RATES OF *SALMONELLA ENTERICA* SEROVAR TYPHIMURIUM

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Summary

Ninety-six pigs (initially 13.8 lb.) were used in a 28-d trial to determine the interactive effects between pelleting and particle size on *Salmonella* serovar Typhimurium shedding and colonization in a young growing pig model. The experiment was a 2 × 2 factorial arrangement consisting of meal or pelleted diets with fine or coarse ground corn. Pigs were fed the diets 1 wk pre-*salmonella* inoculation and allotted based on weight to one of four dietary treatments.

For the main effect of particle size, pigs fed finer ground corn had significantly improved feed efficiency ($P<0.01$) than pigs fed coarser ground corn for the 28 d trial. Pigs fed meal diets had greater ADG, ADFI, and improved F/G ($P<0.05$) than the pigs fed pelleted diets.

Fecal shedding of *salmonella* was low and variable, with no significant differences between main effects ($P<0.26$) or in treatments ($P>0.82$). There was no difference in salmonella infection rates of mesenteric lymph nodes obtained on d 28 between treatments or main effects. Finer grinding and meal diets generally improved growth, feed intake, and feed efficiency compared to pigs fed coarser ground or pelleted feeds. However, particle size or diet form did not alter fecal shedding or mesenteric lymph node infection rates of *salmonella* organisms in our study.

(Key Words: Weanling Pigs, Disease Challenge, *Salmonella*, Particle Size, and Pelleting)

Introduction

Emphasis has been placed on reducing *salmonella* contamination in the slaughter process; this includes implementing strategies on-farm that reduce the prevalence of *salmonella* infections in pigs. Increasing grain particle size and feeding meal diets have been advocated as methods to reduce *salmonella* shedding in growing pigs. European studies have indicated that meal diets that are high in fiber may help in preventing salmonellosis by decreasing the gastric pH content, since *salmonella* and other pathogenic organisms are sensitive to pH. Recently, studies in Denmark have indicated that coarser grinding of pelleted feeds with added formic acid also might reduce the amount of *salmonella* organisms within the intestinal tract but without affecting production. The objective of our study was to establish whether fine or coarse ground meal and pelleted corn based nursery feed affected growth and shedding rates of *Salmonella enterica* serovar Typhimurium.

[1]Food Animal Health and Management Center.

Procedures

Ninety-six pigs (initially 13.8 lb) were blocked by initial weight and allotted to one of four dietary treatments. Two pigs were assigned to a pen, with a total of 12 replicates per treatment.

The four dietary treatments were arranged in a 2 × 2 factorial, with main effects of fine or coarse ground corn and either a meal or pelleted form. All diets were identical in formulation (Table 1) with the only difference being the grain particle size and feed form. To ensure feed was not contaminated within the feed mill, swab samples were taken and cultured for the presence of *salmonella* within the mixer, pellet mill, cooler, as well as the feed ingredients and complete feed samples from each of the diets.

Table 1. Diet Composition (As-fed)[ab]

Ingredient	% of Diet
Corn	51.74
Soybean meal, 46.5% CP	27.94
Spray dried whey	10.00
Select menhaden fishmeal	4.50
Soy oil	3.00
Monocalcium phosphate, 21% P	1.20
Limestone	0.68
Salt	0.35
Vitamin premix	0.25
Trace mineral premix	0.15
Lysine HCl	0.15
DL-Methionine	0.05
Total	100.00%
Calculated Analysis	
Lysine, %	1.39%
ME, kcal/lb	1,553
Ca, %	0.90
P, %	0.80

[a]Diet fed for d 0 to 28 post-weaning.

[b]Diets did not contain antimicrobials or growth promoting levels of zinc oxide or copper sulfate.

All pigs were housed in two environmentally controlled rooms. One feeder and one water-nipple were in each pen to allow ad libitum access to feed and water. Fecal samples were obtained before inoculation to ensure that all pigs were not shedding *salmonella*. Pigs were acclimated to the test diets one week pre-inoculation. Pigs were inoculated on d 7 with 1.9×10^7 CFU of *Salmonella enterica* serovar Typhimurium. Rectal temperatures and feed intakes were determined daily for the first week post inoculation. Pigs were weighed and ADFI, ADG, and F/G were determined on d 0, 7, 14, 21, and 28. Fecal samples were collected on days 14, 21, and 28 to be cultured for the presence of s*almonella*.

A semi-quantitative method for evaluating *salmonella* shedding was developed for the experiment. *Salmonella* growth was classified into one of four categories that included confluent growth over the whole plate (Score 3), any number of wells with growth (Score 2), only growth that was obtained on enrichment (Score 1), or no growth detected (Score 0). On d 27 and 28 of the study, pigs were euthanized and in addition to the fecal sample, an ileocolic lymph node was collected and cultured for the presence of s*almonella*.

All data were analyzed as a 2 × 2 factorial in a randomized complete block design replicating over time using the MIXED model procedure of SAS. All means presented are least-squares means.

Results

A particle size x diet form x week interaction was observed for ADG ($P<0.01$), F/G ($P<0.01$), and a tendency in ADFI ($P<0.08$; Table 2). In the first week of the trial, the pigs fed coarse pelleted diets had lower ADG ($P<0.01$) and worse F/G ($P<0.01$) than all other treatments. While the growth and feed efficiency of this treatment only tended to be the lowest in the other weeks after challenge. The magnitude of the difference in this treat-

ment in the week prior to challenge was responsible for the three-way interaction. Also, there were no significant interactions between week of the study and the main effects of corn particle size or diet form. Therefore, the main effects for pig growth performance corn particle size and diet form were further evaluated (Figures 1 and 2).

For the overall d 0 to 28 period pigs fed meal diets grew faster ($P<0.05$) compared to those fed pelleted diets (Figure 1). Main effect of corn particle size indicated pigs fed fine ground corn had improved feed efficiency ($P<0.01$) compared to pigs fed the coarse ground corn (1.57 vs. 1.85, respectively; Figures 2). Meal-fed pigs had better ($P<0.05$) F/G than those fed pelleted diets.

Fecal samples evaluated for shedding of *salmonella* were collected on d 14, 21, and 28. Since there were no differences in shedding scores by treatment across week or interactions between corn particle size or diet form ($P> 0.79$) main effects are presented in Figure 3. There were no differences ($P>0.23$) in fecal shedding scores due to grain particle size or diet form. In general, shedding was low and variable. An interaction between grain particle size and diet form was not observed for lymph node infection rate ($P>0.82$). Lymph nodes were collected on d 28 for presence of salmonella organisms, and no significant differences were found for main effects of particle size ($P>0.50$) and diet form ($P>0.26$; Figure 4).

Discussion

Finer grinding of the corn improved feed conversion compared to the coarse-ground corn diets. This response to the decreased particle size was as expected, since smaller particles allow for a greater particle surface area to aid digestion of starches. Meal-fed pigs showed improved ADG, ADFI, and feed conversion over the pigs fed pelleted diets. While this result is contradictory to many other studies, we believe this was the result of a feeder by pelleted diet interaction, which may explain this phenomenon, rather than a physical effect of the pelleting process. This was especially evident when feeding the coarse-ground pelleted diet in the first week of the study. The coarse-pelleted diets had a large amount of fines that led to a significant amount of feed wastage. In subsequent weeks, pigs fed the pelleted diets had a significant amount of fines in their feed pan. These fines were collected and weighed back against the amount of feed consumed. However, some of the fines were pushed out of the feeder by the pigs in order to consume more pellets. This loss of fines may explain the discrepancy of F/G and we believe the poorer F/G, was due to feed wastage of the pelleted diets.

This study seems to indicate that the increased amount of *salmonella* shedding associated with pelleted feeds may be due to other factors than an effect of the feed processing methods on the gastro-intestinal environment of the pig. For example the humid environment of the pellet cooler and holding bins may increase the risk of post pelleting contamination. In our study we extensively sampled the feed processing equipment prior to the manufacturing to ensure that the feed was not contaminated during the manufacturing process. Additionally, we evaluated the individual ingredients and the complete feed after manufacture to reduce the risk of introducing a source of salmonella other than the challenge. Additionally, some of the studies evaluating feed processing as a risk factor may have confounded the processing method with the source of ingredients. In these studies, meal based diets were more likely to be manufactured on-farm, while pelleted diets were more likely to be obtained from a large centralized commercial feed mill. These large feed mills may have a higher probability of obtaining ingredients from a larger number of sources and using alternative products that are known to have a higher risk of salmonella contamination. Another factor may be the type of cereal

grain. Many of the studies associating the increased risk have been with wheat or barley based diets. Differences in carbohydrate composition of the diet have been shown to influence the composition of the intestinal microflora. Wheat and barley have different carbohydrate composition, especially in regard to non-starch poly saccharides that may influence the rate of salmonella shedding.

Feed processing has been shown to have beneficial effects on growth. The trial demonstrated improvements in growth and efficiency. However, in contrast to previous research, pelleting did not result in an improvement in growth and feed efficiency. Using this model, we were unable to detect influences of feed processing on fecal shedding and colonization of mesenteric lymph nodes with *salmonella*. Therefore, it appears that the increased risk of fine grinding and pelleting of feeds associated with salmonella shedding reported in other studies may be due to factors other than those confined to the intestinal tract intestinal environment.

Table 2. Corn Particle Size and Pelleting Influence on Growth Performance, Fecal Shedding, and Lymph Node Infection Rates of *Salmonella enterica* Serovar Typhimurium[ab]

	Meal		Pelleted		
Item	Fine	Coarse	Fine	Coarse	SE
D 0 to 7					
ADG, lb	0.56^{c}	0.55^{c}	0.51^{c}	0.28^{d}	0.038
ADFI, lb	0.78^{c}	0.89^{d}	0.73^{c}	0.76^{c}	0.049
F/G	1.44^{c}	1.63^{c}	1.44^{c}	2.89^{d}	0.107
D 7 to 14					
ADG, lb	0.98^{c}	0.99^{c}	0.77^{d}	0.70^{d}	0.065
ADFI, lb	1.37^{cd}	1.56^{c}	1.29^{c}	1.22^{c}	0.079
F/G	1.41^{c}	1.61^{cd}	1.72^{d}	1.85^{de}	0.077
D 14 to 21					
ADG, lb	1.08^{c}	1.06^{de}	0.93^{d}	0.98^{e}	0.054
ADFI, lb	1.63	1.73	1.54	1.56	0.091
F/G	1.51	1.64	1.66	1.60	0.057
D 21 to 28					
ADG, lb	1.17^{c}	1.10^{ce}	0.92^{d}	0.99^{e}	0.054
ADFI, lb	1.86^{c}	1.97^{c}	1.52^{d}	1.77^{cd}	0.102
F/G	1.59^{c}	1.81^{d}	1.78^{d}	1.79^{d}	0.068
D 0 to 28					
ADG, lb	0.95^{c}	0.93^{c}	0.78^{d}	0.74^{d}	0.040
ADFI, lb	1.41^{cd}	1.54^{c}	1.27^{d}	1.33^{d}	0.067
F/G	1.49^{c}	1.67^{d}	1.65^{d}	2.03^{e}	0.046

[a]Ninety-six weanling pigs (initially 13.8 lbs) were used with two pigs per pen and 12 replications (pens) per treatment and inoculated on d 7 with 1.9 x 10^{7} CFU of *Salmonella enterica* serotype Typhimurium.

[b]Fine and coarse ground corn was ground to 500 and 1000 microns respectively. A Particle Size*Diet Form*Week interaction was observed for ADG ($P<0.01$), F/G ($P<0.01$), and a tendency for ADFI ($P<0.08$).

[cde]Treatment means in the same row with different superscripts differ ($P<0.05$).

Corn Particle Size and Pelleting Influence on Growth Performance, Fecal Shedding, and Lymph Node Infection Rates of *Salmonella enterica* Serovar Typhimurium

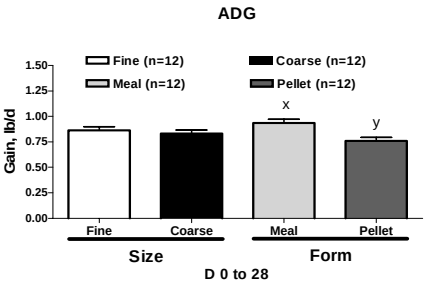

Figure 1.

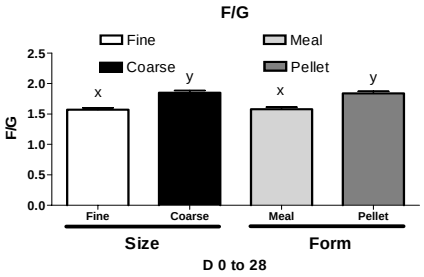

Figure 2.

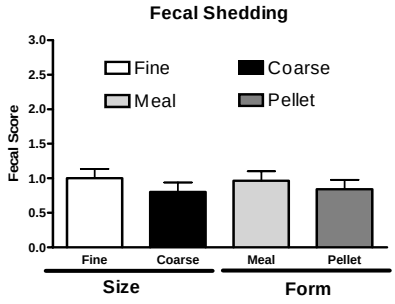

Figure 3.

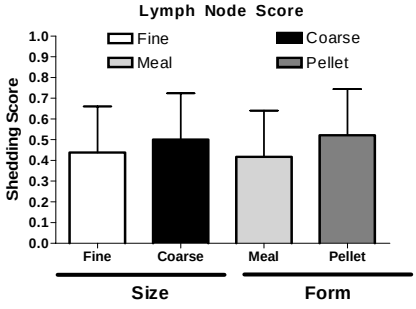

Figure 4.

[a]Ninety-six weanling pigs (initially 13.8 lbs) were used two pigs per pen and 24 replicate pens per main effect of feed processing for ADG, F/G, and lymph node score and 72 replicate pens per main effect for fecal shedding. Inoculated on d 7 with 1.9×10^7 CFU of *Salmonella enterica* serotype Typhimurium.

[xy] Main effects with different superscripts differ ($P<0.05$).

EVALUATION OF HEMICELL® ON GROWTH PERFORMANCE OF LATE NURSERY PIGS[1]

N.A. Lenehan, M.D. Tokach, R.D. Goodband, J.L. Nelssen, S.S. Dritz[2], C.N. Groesbeck, C.W. Hastad, T.P. Keegan, K.R. Lawrence, and M.G. Young

Summary

A total of 276 pigs (initially 21.9 lb) was used to determine the effects of added Hemicell® on growth performance. Hemicell® is a patented fermentation product of Bacillus lentus. The active ingredient in the fermentation product is β-mannanase. However, other enzymes such as amylase, xylanase, cellulases, and α-galactosidase also are present. It is claimed that Hemicell® degrades β-mannan in feed, thus, removing its effects as an antinutritive factor in swine diets. Dietary treatments were arranged as a 2 x 3 factorial, with or without 0.05% Hemicell®, in diets with 3 levels of energy density (1,388, 1,488, 1,588 ME, kcal/lb). The 100 kcal increments were achieved by the addition of wheat bran or soy oil to a corn-soybean meal based diet. The addition of Hemicell® to the diets, regardless of energy level, did not lead to an improvement in growth performance in these late nursery pigs. Increasing energy density of the diet, however, resulted in an improved ADG and F/G.

(Key Words: Weanling Pigs, Hemicell®, Enzyme)

Introduction

A variety of non-starch polysaccharides (NSP) are present in the cell wall structure of many feedstuffs. These NSPs have been shown to diminish growth performance and inhibit nutrient absorption in swine. One class of NSPs are commonly known as hemicelluloses and found in many ingredients used in swine diets, including soybean meal. Soybean meal can contain up to 22.7% NSP on a dry matter basis. Hemicelluloses in soybean meal, specifically galactomannans, are chemically composed of a d-mannose backbone with attached d-galactose molecules. Monogastrics, including pigs, lack the essential enzyme needed to degrade galactomannans. The enzyme, beta-d-mannanase is commercially available as the patented feed additive Hemicell®. Recent studies by Oklahoma State University have suggested that β-mannanase may improve growth performance in weanling and grow-finish pigs, but has minimal effect on nutrient digestibility. Other research has observed a trend for improvement in lean gain in grow-finish pigs fed Hemicell®. Thus, our objective in this study was to determine the effects of Hemicell® inclusion in the diet on

[1]Appreciation is expressed to Roger James of ChemGen Corp., Gaithersburg, Maryland, for providing the Hemicell® enzyme and chemical analysis of the diets.
[2]Food Animal Health and Management Center.

growth performance of late nursery pigs. Three levels of energy density were used in the trial to investigate if Hemicell® will improve energy utilization.

Procedures

A total of 276 pigs (initial BW of 21.9 lb and 32 ± 2 d of age) were used in a 19-d growth assay. Pigs were blocked by weight and allotted to one of six dietary treatments on d 14 postweaning. There were eight pens per treatment. Six replications consisted of six pigs/pen and two replications consisted of five pigs/pen. Pigs were housed in the KSU nursery facility. Each pen was 4 × 5 ft and contained one self-feeder and one nipple waterer to provide ad libitum access to feed and water. Initial temperature was 90°F for the first 5 d after weaning, and was lowered approximately 3°F each week thereafter.

Experimental diets (Table 1) were fed in meal form and were corn-soybean meal based. The trial was conducted using three different energy levels (low, medium, and high), with and without the addition of Hemicell®. The control diets contained 1,488 kcal ME/lb. Wheat bran was added to reduce the dietary energy concentration to 1,388 kcal ME/lb, while energy was increased by the use of soy oil to give an energy content of 1,588 kcal ME/lb for the high energy diets (100 kcal increments). Pigs were allotted on d 14 postweaning. Average daily gain, ADFI and F/G were determined by weighing pigs and measuring feed disappearance on d 21, 28, and 33 postweaning.

Table 1. Composition of Experimental Diets

	Energy Level		
Ingredient, %	Low	Medium	High
Corn	42.95	60.00	55.11
Soybean meal, 46.5%	33.57	36.34	36.76
Soy oil	---	---	4.45
Wheat bran	20.00	---	---
Sand[a]	0.05	0.05	0.05
Monocalcium phosphate, 21% P	1.15	1.38	1.4
Limestone	1.00	0.95	0.95
Salt	0.35	0.35	0.35
Vitamin premix	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15
L-threonine	0.13	0.13	0.13
Lysine HCl	0.25	0.25	0.25
DL-methionine	0.15	0.15	0.15
TOTAL	100.00	100.00	100.00
Total lysine, %	1.45	1.45	1.45
Isoleucine:lysine ratio, %	65%	66%	65%
Leucine:lysine ratio, %	128%	133%	130%
Methionine:lysine ratio, %	34%	34%	34%
Met & Cys:lysine ratio, %	62%	61%	60%
Threonine:lysine ratio, %	67%	67%	66%
Tryptophan:lysine ratio, %	20%	19%	19%
Valine:lysine ratio, %	74%	73%	72%
ME, kcal/lb	1,388	1,488	1,588
Protein, %	22.4	22.0	21.8
Calcium, %	0.75	0.76	0.76
Available phosphorus, %	0.47	0.47	0.47

[a]Hemicell® replaced sand in each diet to provide the additional dietary treatments.

Chemical analyses of the experimental diets for Hemicell® concentrations was performed by ChemGen Corp. The Hemicell® assay results (mmunits/ton) for the diets with and without added Hemicell® are shown in Table 2.

Data were analyzed as a 2 × 3 factorial with or without 0.05% Hemicell® and three levels of energy density (1,388, 1,488, and 1,588 ME, kcal/lb), with pen as the experimental unit. Analysis of variance was performed using the MIXED procedure of SAS. The model included all main effects as well as two-way interactions.

Table 2. Chemical Analysis of Hemicell® in Diets

	Hemicell® (mmunits/ton)[a]	
Energy level	without[b]	With[b]
Low	17.5	107.3
Medium	10.1	104.1
High	9.7	90.2

[a]Hemicell® (mmunits/ton). The expected results at the 1 lb/ton inclusion rate is 100.0 with an assay range of 95.0 to 115.0.
[b]These results indicate normal background levels that are typical in untreated samples.

Results and Discussion

From d 0 to 7, there was no interaction observed between Hemicell® and dietary energy density. Pigs fed diets with added Hemicell® performed similarly to those pigs fed diets without Hemicell® (Table 3). Feed efficiency improved as ME concentration increased from 1,388 to 1,488 Kcal ME, but did not continue to improve in pigs fed diets with 1,588 Kcal ME/lb (quadratic, P<0.05).

From d 7 to 14, there was a tendency for a Hemicell® × energy interaction for ADFI (P<0.06). Pigs fed diets with added Hemicell® showed had decreased ADFI as energy density of the diet increased, whereas ADFI of pigs fed diets without Hemicell® were unaffected by increasing energy density. Average daily gain and F/G was similar for those pigs fed diets with and without Hemicell®. There was a linear improvement in F/G (P<0.01) as energy density of the diet increased.

From d 14 to 19 of the trial, results were similar to those observed d 0 to 14. There was no Hemicell® × energy interaction observed. The effect of Hemicell® was again not shown to be significant (Table 3). A linear increase in ADG and F/G was observed as dietary energy density increased (P<0.01).

Overall, from d 0 to 19, there were no Hemicell® × energy interactions observed. In addition, no effect of Hemicell® was observed. Increasing the energy density of the diet improved (quadratic, P<0.05) ADG and F/G. The greatest improvement in performance occurred as dietary energy density was increased from 1,388 to 1,488 ME, kcal/lb. Similarly, ADFI decreased (quadratic, P<0.05) as energy density of the diet increased.

In summary, addition of Hemicell® did not improve ADG, ADFI, or F/G in this experiment. As the energy density of the diet increased from 1,388 to 1,588 kcal/lb ME, there was a quadratic (P<0.05) improvement in ADG and F/G. The greatest response occurred as dietary energy density increased from 1,388 to 1,488 kcal/lb ME. Increasing energy density of the diet resulted in a reduction in feed intake (quadratic, P<0.05). This trial does not support data from other studies where an improvement in growth performance, due to the addition of Hemicell® in nursery diets, has been observed.

Table 3. Evaluation of Hemicell® on Growth Performance of Late Nursery Pigs[a]

	Treatments										
Hemicell®:	Without			With[b]				P <			
Item ME Kcal/lb:	1,388	1,488	1,588	1,388	1,488	1,588	SE	Hemicell	Hemicell × Energy	Energy Linear	Energy Quadratic
Day 0 to 7											
ADG, lb	0.81	0.89	0.82	0.82	0.86	0.83	0.06	0.931	0.808	0.783	0.064
ADFI, lb	1.25	1.26	1.24	1.25	1.28	1.25	0.06	0.826	0.947	0.770	0.514
F/G	1.56	1.41	1.55	1.55	1.48	1.51	0.06	0.917	0.571	0.575	0.038
Day 7 to 14											
ADG, lb	1.06	1.18	1.12	1.16	1.14	1.14	0.06	0.349	0.165	0.586	0.255
ADFI, lb	1.56	1.63	1.58	1.67	1.60	1.53	0.06	0.733	0.060	0.075	0.362
F/G	1.47	1.38	1.41	1.44	1.41	1.34	0.06	0.282	0.252	0.007	0.359
Day 14 to 19											
ADG, lb	1.06	1.27	1.21	1.11	1.18	1.23	0.06	0.944	0.335	0.008	0.095
ADFI, lb	1.63	1.82	1.66	1.70	1.69	1.67	0.06	0.717	0.199	0.884	0.078
F/G	1.55	1.43	1.38	1.53	1.43	1.36	0.06	0.716	0.926	<.0001	0.415
Day 0 to 19											
ADG, lb	0.98	1.11	1.05	1.03	1.06	1.07	0.03	0.733	0.125	0.035	0.014
ADFI, lb	1.48	1.57	1.49	1.53	1.52	1.48	0.04	0.988	0.136	0.307	0.048
F/G	1.53	1.41	1.44	1.51	1.44	1.41	0.02	0.602	0.282	0.000	0.022

[a]A total of 276 pigs (six replications consisted of six pigs per pen and two replications consisted of five pigs per pen) with an average initial BW of 21.9 lb. Treatment diets were fed from d 0 to 19 of the experiment.

[b]Hemicell® was added at 0.05% of the diet.

EFFECTS OF INCREASING CRYSTALLINE LYSINE WITH OTHER AMINO ACIDS ON GROWTH PERFORMANCE OF 85- TO 135-LB GILTS[1]

M.D. Tokach, R.G. Main[2], S.S. Dritz[2], J.M. DeRouchey, R.D. Goodband, J.L. Nelssen, and J. Usry[3]

Summary

A total of 1,134 gilts (each initially 85 lb, PIC L337 x C22) was used in a 28-d experiment to evaluate the effects of replacing soybean meal with up to 8 lb/ton of crystalline L-lysine HCl with other crystalline amino acids on growth performance. Gilts were randomly allotted to one of six experimental diets. Diets were corn-soybean meal-based with 3% added fat. Diets included a negative control containing 3 lb/ton of L-lysine HCl and formulated to 0.90% true ileal digestible lysine. Two additional diets were formulated with 3 lb/ton L-lysine to 1.0% true ileal digestible lysine but with or without crystalline threonine and methionine to compare threonine to lysine ratios of 60 versus 65% and methionine & cystine (TSAA) ratios of 55 vs. 60%. The three remaining diets contained 6, 7, or 8 lb/ton of L-lysine HCl with crystalline threonine and methionine to provide the same ratios relative to lysine of 65 and 60%, respectively.

Pigs fed the negative control diet (0.90 true ileal digestible lysine) had decreased ADG, poorer F/G, and were lighter at then end of the trial than pigs fed the diet containing 3 lb/ton L-lysine with added L-threonine and DL methionine (P<0.05). This indicates that diets containing 1.0% true ileal digestible lysine were not over the pigs' lysine requirement. Pigs fed 1.0% true ileal digestible lysine with high threonine and TSAA ratios (65 and 60% relative to lysine, respectively) had similar ADG but tended to have better (P<0.08) F/G than those fed the lower threonine and TSAA ratios. Using 6, 7, or 8 lb/ton of L-lysine HCl with added threonine and methionine in diets formulated to 1.0% true ileal digestible lysine had no effect on ADG or F/G, but did tend to decrease ADFI (linear, P<0.04; quadratic P<0.07). These results suggest that the use of up to 8 lb/ton of L-lysine HCl in conjunction with L-threonine and DL methionine to maintain proper amino acid to lysine ratios will not negatively affect pig performance. In addition, increasing the true ileal digestible threonine:lysine (60 to 65%) and TSAA:lysine ratios (55 to 60%) improved F/G in this experiment.

(Key Words: Crystalline Amino Acids, Growing Pigs, Performance)

Introduction

Last year the first commercial production facility dedicated to L-threonine production was opened in the United States. As a result,

[1]The authors would like to thank Ajinomoto Heartland LLC, Chicago, Illinois, for providing the crystalline amino acids used in this study and partial financial support.
[2]Food Animal Health and Management Center.
[3]Anjinomoto Heartland LLC, Chicago, Illinois.

L-threonine has become more widely available and less expensive for use in swine diets. If economically feasible, the use of L-threonine would allow for greater amounts of L-lysine to be used than the typical 3 lb/ton inclusion and less soybean meal. This will have environmental advantages by further decreasing nitrogen concentration in swine waste by another 20% compared with adding 3 lb/ton L-lysine alone. However, the key to adding greater than 3 lb/ton of L-lysine and other amino acids is an understanding of the correct amino acid ratios relative to lysine so deficiencies do not result in poorer pig growth performance. Therefore, the objective of this study was to evaluate the effects of increasing L-lysine HCl in finishing pig diets held at a constant percentage of true ileal digestible lysine (1.0%).

Procedures

A total of 1,134 gilts (each initially 85 lb, PIC L337 x C22) was used in a 28-d experiment. There were a total of 42 pens with 27 pigs per pen, 7 pens (observations) per treatment. Pens of gilts were randomly allotted to one of six experimental diets (Table 1). Diets were corn-soybean meal-based with 3% added fat and included a negative control containing 3 lb/ton of L-lysine HCL and formulated to 0.90% true ileal digestible lysine. Two additional diets were formulated with 3 lb/ton L-lysine to 1.0% true ileal digestible lysine but with or without crystalline threonine and methionine. This provided a comparison of threonine to lysine ratios of 60 and 65%, and methionine and cystine (TSAA) ratios of 55 and 60%. The three remaining diets contained 6, 7, or 8 lb/ton of L-lysine HCl, with crystalline threonine and methionine to provide the same ratios relative to lysine of 65 and 60%, respectively. Pigs and feeders were weighed on d 0, 14, and 28 to calculate ADG, ADFI, and F/G.

Data were analyzed using the PROC MIXED procedures of SAS as a randomized complete block design. Pen was the experimental unit. Contrasts were used to compare pigs fed the negative control diet (0.90% true ileal digestible lysine) to the mean of pigs fed the 1.0% true ileal digestible lysine diet from 3 lb/ton L-lysine HCl. Also, threonine and TSAA ratios of 60 and 65% and 55 and 60%, respectively were compared. Finally, linear and quadratic effects of increasing L-lysine HCl were evaluated.

Results and Discussion

An important experimental consideration when conducting studies designed to determine the correct ratio of amino acids relative to lysine, or evaluating high inclusion rates of L-lysine HCl on pig growth is that the experimental diets are not formulated above the pigs' lysine requirement. If diets happen to be above the pigs' requirements, it is possible that concentrations of other amino acids are also above their requirements. If this were the case, we would erroneously assume efficient utilization of high levels of L-lysine HCl, as pigs would have similar performance as controls. To verify that our experimental true ileal digestible lysine concentration of 1.0% was not too high, we fed pigs a negative control diet containing 0.90% true ileal digestible lysine. Pigs fed the negative control diet (0.90 true ileal digestible lysine) had decreased ADG, poorer F/G, and were lighter at then end of the study than pigs fed the diet containing 3 lb/ton L-lysine with added L-threonine and DL methionine ($P<0.05$). This indicates that diets containing 1.0% true ileal digestible lysine were not over the pigs' lysine requirement.

Pigs fed 1.0% true ileal digestible lysine with high threonine and TSAA ratios (65 and 60% relative to lysine, respectively) had similar ADG but tended to have better ($P<0.08$) F/G than those fed the lower threonine and TSAA ratios. Using 6, 7, or 8 lb/ton of L-lysine HCl with added threonine and methionine in diets formulated to 1.0% true ileal di-

gestible lysine had no effect on ADG or F/G, but did tend to decrease ADFI (linear, $P<0.04$; quadratic $P<0.07$). These results suggest that the use of up to 8 lb/ton of L-lysine HCl in conjunction with L-threonine and DL methionine to maintain proper amino acid to lysine ratios will not negatively affect pig performance.

In conclusion, the use of up to 8 lb/ton of L-lysine combined with L-threonine and DL-methionine appears to be an effective substitution for soybean meal in diets for pigs from 85 to 130 lb. Depending on ingredient costs, replacing soybean meal with crystalline amino acids may lower diet cost. It will also have an environmental impact, as swine waste will contain less nitrogen.

Table 1. Experimental Diet Composition (As-fed Basis)

	Added L-Lysine HCl lb/ton					
	3	3	3	6	7	8
	True Ileal Digestible Lysine, %					
	0.90	1.0	1.0	1.0	1.0	1.0
	TSAA:Lysine Ratio, %					
	60	60	55	60	60	60
	Threonine:Lysine Ratio, %					
	65	65	60	65	65	65
Corn	70.32	66.35	66.46	70.72	72.16	73.64
Soybean meal, 46.5%	23.52	27.50	27.49	22.83	21.30	19.74
Choice white grease	3.00	3.00	3.00	3.00	3.00	3.00
Monocalcium P, 21% P	1.35	1.30	1.30	1.35	1.35	1.35
Limestone	1.05	1.05	1.05	1.05	1.05	1.05
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix with phytase	0.08	0.08	0.08	0.08	0.08	0.08
Trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10
Copper sulfate	0.03	0.03	0.03	0.03	0.03	0.03
L-threonine	0.04	0.05	---	0.11	0.14	0.16
Lysine HCl	0.15	0.15	0.15	0.30	0.35	0.40
DL-methionine	0.03	0.05	---	0.09	0.11	0.12
Total	100.00	100.00	100.00	100.00	100.00	100.00
Total lysine, %	1.01	1.12	1.12	1.11	1.11	1.10
True ileal digestible amino acids, %						
Lysine	0.90	1.00	1.00	1.00	1.00	1.00
Isoleucine:lysine ratio	69	69	69	61	59	56
Leucine:lysine ratio	156	150	150	139	135	131
Methionine:lysine ratio	31	31	27	34	35	35
Met & Cys:lysine ratio	60	60	55	60	60	60
Threonine:lysine ratio	65	65	60	65	65	65
Tryptophan:lysine ratio	19	19	19	17	16	15
Valine:lysine ratio	79	77	77	70	67	64
ME, kcal/lb	1,560	1,559	1,561	1,555	1,554	1,553
Protein, %	16.9	18.4	18.4	16.6	16.0	15.4
Calcium, %	0.75	0.75	0.75	0.75	0.74	0.74
Phosphorus, %	0.64	0.65	0.65	0.64	0.63	0.63
Available P, %	0.39	0.38	0.38	0.39	0.38	0.38
Lysine:calorie ratio, g/mcal	2.94	3.26	3.26	3.23	3.23	3.22
Avail P:calorie ratio g/mcal	1.13	1.11	1.11	1.13	1.12	1.12

Table 2. Effects of Increasing Crystalline Lysine with Other Amino Acids on Growth Performance of 85- to 135-lb Gilts

	Added L-Lysine HCl lb/ton											
	3	3	3	6	7	8						
	True Ileal Digestible Lysine, %											
	0.90	1.0	1.0	1.0	1.0	1.0						
			TSAA:Lysine Ratio, %									
	60	60	55	60	60	60						
	Threonine:Lysine Ratio, %							Model	Contrasts[d], P <			
Item	65	65	60	65	65	65	SED	P <	1	2	3	4
Initial wt, lb	85.2	85.1	85.2	85.5	85.1	85.2	0.73	0.99	0.90	0.99	0.67	0.97
ADG, lb	1.79	1.92	1.88	1.93	1.91	1.87	0.04	0.03	0.01	0.39	0.20	0.40
ADFI, lb	3.86	3.98	3.97	3.99	3.92	3.80	0.07	0.09	0.11	0.04	0.07	0.40
F/G, lb	2.17	2.08	2.11	2.06	2.05	2.04	0.04	0.03	0.09	0.27	0.84	0.08
Final wt, lb	135.3	138.9	137.8	139.3	138.8	137.5	1.23	0.04	0.01	0.40	0.23	0.42
Feed cost/lb of gain, $[c]	0.143	0.142	0.142	0.141	0.140	0.139	0.003	0.80	0.66	0.37	0.84	0.55
IOFC, $/hd[c]	13.03	14.04	13.78	14.16	14.12	13.67	0.38	0.06	0.01	0.51	0.25	0.48

[a]A total of 1,134 gilts (PIC L337 x C22) with 27 pigs per pen was used.
[b]28-day weights, adjusted to a common start weight.
[c]Feed cost and income over feed cost (IOFC) were calculated using $ 2.40 / bu corn, $180/ton 46.5% SBM, $0.76/lb Lysine, $1.20/lb Methionine, $ 1.20/lb threonine.
[d]Contrasts: 1=0.90 true ileal digestible lysine vs 1.0 true ileal digestible lysine with 3 lb of added lysine and 65% Threonine:Lysine ratio. 2 = linear effect of increasing L-lysine HCl. 3 = quadratic effect of increasing L-lysine HCl. 4 = TSAA ratio of 55 vs 60% in diets with 1.0% true ileal digestible lysine.

Swine Day 2003

ADDED FAT IN DIETS FOR PIGS IN EARLY AND LATE FINISHING

E.C. Baudon, J.D. Hancock, and N. Llanes

Summary

A total of 416 pigs, with an average initial body weight of 127 lb, was used to determine the effect of adding fat in diets for early and late finishing on growth performance and carcass characteristics. Treatments were: a no added fat control; addition of fat in early finishing (127 to 219 lb body weight); addition of fat in late finishing (219 to 280 lb body weight); and addition of fat throughout finishing (127 to 280 lb body weight). For the first period (127 to 219 lb body weight), ADG and F/G were improved by 5 and 9%, respectively, when fat was added in the diet ($P<0.03$). For the second period (219 to 280 lb body weight) and overall (127 to 280 lb body weight) ADFI was less for pigs fed fat ($P<0.003$). Also, overall ADG and F/G were improved with inclusion of fat ($P<0.07$), with the greatest response from inclusion of fat in both phases. Hot carcass weight and carcass yield were increased with inclusion of fat in the diets ($P<0.001$), and this effect was more pronounced when fat was added in late finishing vs early finishing ($P<0.02$). In conclusion, the addition of fat to diets for finishing pigs improved growth performance without decreasing carcass leanness. However, adding fat for only the first or second part of the finishing phase was less effective than adding fat for the entire finishing period.

(Key Words: Fat, Finishing, Carcass)

Introduction

Feed-grade fat sources are commonly added to diets for growing-finishing pigs to improve growth performance and especially feed efficiency. Indeed, review of experiments at Kansas State University indicates that for every 1% added fat, there should be about a 2% improvement in feed efficiency. This improvement in efficiency of growth must be balanced against the likely increase in diet cost when fat is added, but if prices are right, adding fat to swine diets can improve efficiency and economy of gain. However, there are anecdotal reports that the response to adding fat is greatly reduced or even nonexistent in late finishing. Thus, we conducted an experiment to determine the effect of including fat in early vs late finishing on growth performance, carcass measurements, and economy of gain.

Procedure

A total of 416 pigs in two groups (one in fall-winter and one in winter-spring), with an average starting weight of 127 lb, was blocked by sex and weight and assigned to pens. The 32 pens held 13 pigs each and had half slatted/half solid concrete flooring. They were equipped with a nipple waterer and two-hole self feeder to allow ad libitum consumption of feed and water. Treatments were: a no added fat control; addition of fat in early finishing (127 to 219 lb body weight, fed for 42 d); addition of fat in late finishing (219 to 280 lb body weight, fed for 30 d); and addition of fat throughout finishing (127 to 280 lb body weight, fed for 72 d).

The diets (Table 1) were formulated to meet or exceed all NRC suggested requirements. Lysine:calorie ratios were kept con-

stant for all diets in early and late finishing, and additions of vitamin and minerals also were adjusted to keep constant ratios with caloric content of the diets. The pigs and feeders were weighed at the beginning and the end of each portion of the experiment to allow calculation of ADG, ADFI, and F/G. Furthermore, at an average weight of 280 lb, the pigs were slaughtered to allow collection of routine carcass measurements (i.e., hot carcass weight and backfat thickness).

All data were analyzed using the PROC MIXED Procedure of SAS with orthogonal contrasts used to separate treatment means. Finally, hot carcass weight was used as a covariate for analyses of the data for dressing percentage and backfat thickness.

Results and Discussion

For the period from 127 to 219 lb body weight (Table 2), inclusion of 6% soybean oil improved ADG by 5% ($P<0.03$) and F/G by 9% ($P<.0001$). Also, ADFI decreased from 6.3 lb to 5.99 lb when fat was added to the diets ($P<.0001$). These results are in general agreement with previous research in that fat inclusion in diets for growing pigs generally results in greater rate and especially efficiency of gain.

For 219 to 280 lb body weight (Table 3), ADFI was less ($P<0.003$) for the pigs fed diets with added fat. Overall (i.e., 127 to 280 lb), ADG, ADFI and F/G were improved with fat added to the diets ($P<0.07$). There also was improved ADG and F/G with addition of fat throughout finishing compared to fat addition being restricted to only a portion of the finishing period ($P<0.004$). Improvements in ADG, ADFI, and F/G were 6, 4, and 9% when fat was added during both phases vs the control. It is important to note there were no interactions among the treatments with fat added in the first vs second portion of the finishing phase, thus indicating there is no carryover effect when feeding fat in early vs late finishing.

As for carcass measurements, we noted that HCW and carcass yield (i.e., dressing percentage) were increased as fat was added in the diets ($P<0.001$). Also, HCW and carcass yield were greater with fat added late in finishing vs early in finishing and then being removed ($P<0.02$).

In conclusion, adding fat improved overall growth performance of pigs without decreasing carcass leanness. The best results were obtained when fat was included for the entire finishing phase. However economics may dictate that a high inclusion of fat during the finishing phase is not the best option. Thus, level of inclusion of fat during the finishing period must be chosen with careful attention to expected responses in growth performance and the price of fat vs other energy sources (e.g., corn) at any given time.

Table 1. Diet Composition[a]

	Phase 1 (127 to 219 lb)		Phase 2 (219 to 280 lb)	
Ingredient (%)	No fat	Fat	No fat	Fat
Corn	74.21	68.21	81.73	75.55
Soybean meal, 46.5%	23.41	23.19	16.14	16.14
Soy oil	0.00	6.00	0.00	6.00
Monocalcium phosphate	0.60	0.70	0.50	0.59
Limestone	1.03	0.98	1.00	0.95
Salt	0.35	0.38	0.30	0.33
Vitamin premix	0.15	0.17	0.13	0.14
Trace mineral premix	0.15	0.16	0.10	0.11
Antibiotic[b]	0.10	0.11	0.10	0.11
L-Lysine HCl	0.00	0.12	0.00	0.10

[a]Phase 1 diets had a lysine/calorie ratio of 2.7 g/Mcal; Phase 2 had a lysine/calorie ratio of 2.1 g/Mcal.
[b]Provided 80g/ton tylosin.

Table 2. Added Fat and Growth Performance in Early Finishing

	Treatment			
Item	No fat	Fat	SE	P value
Phase 1 (127 to 219 lb)				
ADG, lb	2.16	2.26	0.06	0.03
ADFI, lb	6.30	5.99	0.26	0.001
F/G	2.91	2.66	0.07	0.001

Table 3. Effects of Added Fat on Growth Performance in Late Finishing and on Carcass Measurements

	Treatment								
Item	No fat	No fat/fat	Fat/ no fat	Fat	SE	No fat vs other	Nf/fat+F/Nfat vs Fat	Nf/fat vs F/Nfat	Interaction Phase1XPhase2
Phase 2 (219 to 280 lb)									
ADG, lb	1.92	1.92	1.81	1.95	0.06	-	-	-	-
ADFI, lb	6.91	6.60	6.72	6.55	0.17	0.003	-	-	-
F/G	3.60	3.44	3.71	3.36	0.12	-	-	-	-
Overall									
ADG, lb	2.04	2.08	2.04	2.16	0.04	0.07	0.004	-	-
ADFI, lb	6.53	6.46	6.25	6.29	0.21	0.001	-	0.005	-
F/G	3.20	3.11	3.06	2.91	0.06	0.001	0.001	-	-
Carcass characteristics									
Hot carcass wt, lb	199.8	207.0	201.4	210.5	5.7	0.001	0.002	0.02	-
Yield, %	72.2	73.7	72.6	73.2	0.7	0.001	-	0.003	-
Backfat, in	0.84	0.84	0.83	0.87	0.04	-	0.08	-	-
Lean, %	52.8	53.3	53.0	53.2	0.4	0.06	-	-	-

Dashes indicate P = 0.15 or greater.

Swine Day 2003

EFFECT OF ADDED FAT ON PERFORMANCE OF GROWING-FINISHING PIGS IN COMMERCIAL CONDITIONS

M.G. Young, M.D. Tokach, S.S. Dritz[1], R.D. Goodband, and J.L. Nelssen

Summary

A total of 1,040 pigs (half barrows and half gilts) was used in a 42-day experiment conducted in a commercial research facility to determine the influence of graded levels of added fat on growth performance, feed cost per pound of gain and margin over feed of growing-finishing pigs. The four dietary treatments were based on level of added dietary fat (0, 2, 4, or 6%), with the diets fed for a six-week period from 158 to 232 lb. Adding fat to the diet for pigs weighing 158 to 232 lb decreased ADFI, improved feed efficiency, increased cost per pound of gain and had no effect on income over feed cost. The economics of whether fat should be added to the growing finishing pig diet will depend on the cost of corn, soybean meal and fat. The results of this experiment demonstrate that, with current prices, the lowest cost per pound of gain was obtained when no fat was added to the diet for pigs from 158 to 232 lb. But because of the numerically greater ADG income over feed cost (IOFC) was numerically similar when fat was added to the diet.

(Key Words: Added Fat, Growing-Finishing Pigs)

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 and feed efficiency are expected to increase 1% and 2%, respectively, for every percent of added fat. However, several questions arise regarding this rule of thumb. First, is the response to added fat the same at all levels of fat addition (i.e., is the response from increasing dietary fat from 0 to 2% the same as increasing fat level 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 for this is that feed intake is normally 25 to 40% higher in university research settings than under field conditions. In a previous experiment with pigs conducted in commercial conditions, where pigs were fed diets with 0, 2, 4, or 6% fat from 80 to 265 lb, a linear improvement in daily gain was observed up to 130 lb, while feed efficiency improved linearly due to fat addition in all weight intervals over the total experiment. Therefore, the objective of this experiment was to determine the influence of graded levels of added fat (0 to 6%) on growth performance, feed cost per pound of gain and margin over feed of growing-finishing pigs reared in a commercial research facility.

[1]Food Animal Health and Management Center.

Procedures

The experiment was conducted in a commercial research facility. Pigs were allotted randomly to pens on entry to the barn. Forty pens (20 of barrows and 20 of gilts) with approximately 26 pigs per pen were used in the experiment. The finishing facility was a double curtain-sided deep pit barn that operated on natural ventilation during the summer and mechanical ventilation during the winter. The barn had a totally slatted floor with 7.2 ft^2 provided per pig. Each pen was equipped with a four-hole dry self-feeder and one cup waterer. The experiment was conducted from mid-April to the end of May.

The four dietary treatments were based on level of added dietary fat (0, 2, 4, or 6%). The diets were fed for a 6-week period from 158 to 232 lb. All diets were corn-soybean meal based and formulated to a constant lysine to calorie ratio with similar levels of vitamins and minerals (Table 1). Pigs were weighed and feed disappearance was determined every 14 days. Data were analyzed using the MIXED procedure of SAS for linear and quadratic effects with pen serving as the experimental unit of analysis.

Results and Discussion

During the first two weeks of the experiment (158 to 184 lb), ADG and F/G to improved linearly ($P<0.01$) as dietary fat level increased from 0 to 6% (Table 2). Average daily feed intake was not influenced by fat addition to the diet. For the second two-week period (184 to 208 lb), there was no response in ADG to added dietary fat, but ADFI decreased and F/G improved linearly ($P<0.01$) as added dietary fat increased from 0 to 6%. Similarly, during the final two weeks of the trial (208 to 232 lb), no response in ADG to added fat was observed, while ADFI decreased and F/G improved linearly ($P<0.01$).

For the overall period there was no response in ADG to added fat, while ADFI decreased and F/G improved linearly ($P<0.01$) as the level of fat in the diet increased. Feed cost per pound of gain was lower ($P<0.05$) for the 0% added fat diet compared to the added fat diets. Also, feed cost per pound of gain was lower ($P<0.05$) for pigs fed the diet containing 4% fat compared with those fed the 6% added fat diet. Income over feed cost averaged $20.8/pig but did not differ regardless of the level of fat added to the diet. Average pig weight on day 14 of the trial tended ($P<0.07$) to increase as the level of fat in the diet increased, but initial, day 28 and final pig weights were not different.

There was no treatment by sex interactions ($P>0.10$). During the first two weeks of the experiment, ADFI was lower ($P<0.01$) and F/G was improved ($P<0.02$) for gilts compared with barrows (Table 3). For the second two-week period, ADG was greater ($P<0.02$) for barrows and ADFI was lower ($P<0.01$) for gilts. During the final two-week period, there was a tendency ($P<0.07$) for ADG to be greater for gilts, while F/G and feed cost per pound of gain was lower ($P<0.01$) for gilts compared with barrows. Barrow weight at the end of the first two weeks of the trial tended ($P<0.07$) to be greater, while at the end of the second two-week period were greater ($P<0.02$) than gilts.

Using the economic data presented in Table 2, adding fat to the diet for pigs weighing 158 to 230 lb increased cost per pound of gain and had no effect on income over feed cost. For the first two weeks of the experiment there was a tendency for ADG to be greater when fat was added to the diet, with pigs fed the 4 or 6% added fat diet being 1 lb heavier compared to those fed the 0% added fat diet. This would indicate that pigs were in an energy deficit for a short period at the start of the experiment. The economics of whether fat

should be added to the growing finishing pig diet will depend on the cost of corn, soybean meal and fat and the value of additional gain. The results of this experiment demonstrate that, with current prices, the lowest cost per pound of gain was obtained when no fat was added to the diet for pigs from 158 to 232 lb.

Table 1. Composition of Experimental Diets (As-fed Basis)

	Added fat, %			
Item	0	2	4	6
Corn	77.40	74.10	71.15	67.85
Soybean meal (46.5%)	20.55	21.85	22.75	24.05
Choice white grease	-	2.00	4.00	6.00
Monocalcium phosphate (21% P)	0.50	0.54	0.57	0.60
Limestone	0.85	0.85	0.84	0.84
Salt	0.35	0.35	0.35	0.35
Vitamin premix[a]	0.08	0.08	0.08	0.08
Trace mineral premix	0.10	0.10	0.10	0.10
L-Lysine HCl	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00
Calculated Analysis				
Lysine, %	0.94	0.97	0.99	1.02
ME, kcal/lb	1,519	1,560	1,600	1,641
Protein, %	16.1	16.5	16.6	16.9
Calcium, %	0.51	0.52	0.52	0.53
Total phosphorous, %	0.46	0.46	0.47	0.48
Available phosphorous, %	0.25	0.25	0.26	0.27
Lysine:calorie ration, g/mcal	2.81	2.82	2.81	2.82

[a]Includes 136,050 FTU phytase units.

Table 2. Effect of Added Fat on Performance of Grow-Finish Pigs in Commercial Facilities

	Added fat, %					P<	
	0	2	4	6	SED	Linear	Quadratic
Day 0-14							
ADG, lb	1.85	1.83	1.90	1.92	0.05	0.07	0.68
ADFI, lb	5.25	5.16	5.15	5.09	0.10	0.15	0.90
Feed/gain	2.84[a]	2.82[a]	2.71[b]	2.65[b]	0.05	0.01	0.65
Day 15-28							
ADG, lb	1.74	1.71	1.75	1.71	0.05	0.81	0.81
ADFI, lb	5.60[a]	5.41[b]	5.24[c]	5.11[c]	0.08	0.01	0.56
F/G	3.23[a]	3.17[ab]	2.99[c]	3.01[bc]	0.08	0.01	0.56
Day 29-42							
ADG, lb	1.70	1.60	1.66	1.71	0.06	0.13	0.64
ADFI, lb	5.56[a]	5.26[b]	5.13[b]	5.12[b]	0.17	0.01	0.10
F/G	3.30[ab]	3.31[a]	3.12[bc]	3.00[c]	0.09	0.01	0.30
Day 0-42							
ADG, lb	1.76	1.72	1.77	1.78	0.03	0.27	0.27
ADFI, lb	5.47[a]	5.28[b]	5.17[b]	5.10[c]	0.08	0.01	0.32
F/G	3.11[a]	3.08[a]	2.92[b]	2.87[c]	0.03	0.01	0.65
Feed cost/lb gain[d]	0.164[a]	0.170[bc]	0.168[b]	0.172[c]	0.002	0.01	0.50
IOFC, $/pig[ef]	21.10	20.24	21.02	20.80	0.45	0.80	0.29
Weight, lb[g]							
Day 14	183.6	183.9	184.7	184.6	0.67	0.07	0.64
Day 28	207.9	208.3	209.2	209.0	0.97	0.18	0.62
Day 42	231.9	230.9	232.5	233.2	1.47	0.24	0.44

[abc]Means with different superscript letter differ (P<0.05).
[d]Corn = $ 0.04/lb, soybean meal = $ 0.091/lb, choice white grease = $ 0.13/lb.
[e]Income Over Feed Cost.
[f]Pig price = $45/cwt.
[g]Average initial weight 157.8 lb.

Table 3. Performance of Barrows and Gilts in Grow-Finish in Commercial Facilities

	Gender			
	Barrows	Gilts	SED	P<
Day 0-14				
ADG, lb	1.91	1.85	0.04	0.20
ADFI, lb	5.37	4.96	0.10	0.01
F/G	2.82	2.69	0.04	0.02
Day 15-28				
ADG, lb	1.81	1.65	0.05	0.02
ADFI, lb	5.69	4.99	0.12	0.01
F/G	3.15	3.04	0.11	0.37
Day 29-42				
ADG, lb	1.61	1.72	0.05	0.06
ADFI, lb	5.44	5.09	0.22	0.16
F/G	3.40	2.96	0.09	0.01
Day 0-42				
ADG, lb	1.78	1.74	0.04	0.36
ADFI, lb	5.50	5.01	0.14	0.01
F/G	3.10	2.89	0.07	0.02
Feed cost/lb gain[a]	0.174	0.162	0.004	0.02
IOFC, $/pig[bc]	20.59	21.03	0.61	0.50
Ending weight, lb[d]				
Day 14	184.9	183.6	0.60	0.07
Day 28	210.3	206.9	1.12	0.02
Day 42	233.1	231.2	1.64	0.27

[a]Corn = $ 0.04/lb, soybean meal = $ 0.091/lb, choice white grease = $ 0.13/lb.
[b]Income Over Feed Cost.
[c]Pig price = $45/cwt.
[d]Average initial weight 160 lb for barrows and 155.6 lb for gilts.

DIETARY ENERGY DENSITY AND GROWING-FINISHING PIG PERFORMANCE AND PROFITABILITY

M.G. Young, M.D. Tokach, S.S. Dritz[1], J.M. DeRouchey, R.D. Goodband, and J.L. Nelssen

Summary

A retrospective analysis of 25 studies (16 at university and 9 at field research facilities) was conducted to model the response in ADG and F/G to increasing dietary energy density and its effect on profitability. Average daily feed intake in the field studies was approximately 30% lower than in the university studies, and as pigs increase in weight in the university studies they transition to a non-energy dependent phase of growth at a lighter weight than those in the field studies. The percentage response in ADG per percent added fat in the university studies was greater for the first 2.5% added fat than for higher fat levels, indicating a diminishing return. However, the percentage response in ADG was similar for both the 2.5 and 5% added fat levels in the field studies, indicating a linear response to fat additions. As expected the F/G improvement was greater in the field compared to the university studies.

A five-year price series was used to determine the impact of fat additions to corn-soybean meal-based diets on profitability. For lighter weight pigs (70 to 120 lb), the net return to added fat is almost always positive, with feed cost per unit of gain being increased and deceased 50% of the time. However, the net return to added fat for heavier weight pigs (230 to 265 lb) fluctuates, with feed cost per unit of gain being increased in most scenarios. Using high energy diets for lighter weight pigs is cost effective and increases profit the majority of the time. The optimal energy density for late finishing pig diets is more dependent on the economic conditions.

(Key Words: Growing-Finishing Pigs, Energy Density, ADG)

Introduction

In many countries the energy density of growing-finishing pig's diets is set at the desired level, and diets are formulated by least cost formulation using the available energy sources to meet these energy levels. Contrarily in the United States, energy density of growing-finishing pig diets is generally allowed to float, with dietary energy density being dictated by the available energy sources and their cost competitiveness.

Several studies have been conducted to determine the influence of dietary energy density of growing-finishing pig diets on pig performance and carcass composition. Increasing energy density by adding fat to diets for growing-finishing pigs typically improves ADG and feed efficiency and reduces ADFI. Most of the early studies evaluating dietary added fat were conducted in university research facilities with low animal density and good en-

[1]Food Animal Health and Management Center.

vironments, which result in higher feed intakes and growth rates than those that occur in commercial swine production. The availability of data from field research barns has allowed the documentation of field versus university facility responses to dietary energy density. The lower feed intakes in a commercial environment make a favorable response to higher energy density diets more likely, and perhaps larger.

Modern pigs are genetically leaner and have lower feed intake, which makes it more likely these pigs will respond to increased energy intake with increased growth rate and less likely they will become fatter. The move to all-in all-out systems has increased the emphasis on ADG for throughput to improve site utilization. Also, the packer's penalty for selling below the optimal market weight has increased greatly. This is especially critical during the summer because of the seasonal reduction in ADG.

Although we have conducted numerous experiments to examine the energy density of finishing diets, a composite summary of trials has not been available. Thus, our objective was to do a retrospective analysis of 25 energy density experiments conducted by Kansas State University in the last 13 years to evaluate the response in pig performance to dietary energy density and its effect on profitability.

Procedures

Twenty five studies have been conducted to evaluate the effect of diet energy density on the performance of growing-finishing pigs. Sixteen of the studies were conducted in university facilities with a total of 2,144 pigs, while 9 were conducted in field research facilities with a total of 9,899 pigs. The studies conducted at both the university and field research facilities utilized barrows, gilts, and mixed sex groups. For the studies conducted at the university facilities, pigs were housed in groups of 2 to 6 pigs per pen, on totally slatted floors and given ad libitum access to feed and water. The field data were collected in 2 production systems with either PIC 327 or PIC 337 sired pigs. Under field conditions, pigs were housed in groups of 20 to 25 per pen on totally slatted floors and allowed ad libitum access to feed and water.

The data were analyzed for the percentage change in ADG and F/G per percentage added dietary fat using the Proc Mixed procedure of SAS. The model included pig body weight, feed intake as a percentage of body weight, location (field or university), dietary fat level and the location × dietary fat level interaction. After the retrospective analysis was completed, we used a 5-year price series from southern Minnesota to determine the economic impact of dietary fat additions during various stages of the grow-finish phase.

Results and Discussion

From the retrospective analysis of the 25 energy density studies, prediction equations to determine ADFI as a percentage of body weight and the response in ADG and F/G per percentage added fat in growing-finishing pig diets were determined (Table 1). From the studies conducted under field conditions, ADFI was up to 30% lower than in the university research studies (Figure 1). Also, feed intake plateaus at about 200 lb in the field studies while continuing to increase in the university studies. This indicates that in university studies, as pigs increase in weight, they transition to a non-energy dependent phase of growth at a lighter weight compared to those in the field. Therefore, the improvement in growth rate to increased dietary energy density from adding fat decreases with increasing body weight in the university data. However, in the data from field studies where feed intake does not increase rapidly with the in-

crease in body weight, this decrease in response is at a slower rate.

In the field studies, the percentage increase in ADG per percentage added fat was relatively similar regardless of the dietary energy density or added fat level (Figure 2). However, in the university setting, the response was greater for the first 2.5% added fat than when adding 5% fat. For example, adding 2.5% fat to the diet of pigs weighing 115 lb results in a 2% improvement in ADG, while adding 5% fat only results in a 2.1% improvement in ADG. This suggests a quadratic response to adding fat to the diet with little benefit in ADG to adding more than 2.5% fat. The practical application of this is that for farms where pigs are achieving high levels of feed intake, the value of increasing ADG with dietary energy density is less and the transition away from the energy dependent phase of growth will occur at a lighter weight.

The improvement in F/G in the university studies per percentage added fat was similar for both the 2.5 and 5% added fat levels, with the improvement decreasing with increasing body weight (Figure 3). As a result of the lower feed intake and greater ADG response in the field studies, the improvement in F/G was greater than in the university studies.

To evaluate the economics of increasing energy density (added fat) of growing-finishing pig diets, a number of important questions need to be answered. First, is your production system short on days for your pigs to reach the ideal market weight? Second, what is the value of ADG in your production system? If added fat improves ADG, the value of the gain must be included in the economic analysis. If extra finishing space is available, this value may be zero, as pigs could be left in the barn additional days to reach the same end weight. However, if finishing space is short, the extra weight is at least worth market price or could be worth more than market price if the additional weight helps move pigs into the packer's optimal weight window, reducing weight discounts.

Increasing energy density of growing-finishing pig diets by adding fat will increase diet cost, but because of the importance of energy intake in driving average daily gain and market weight, high energy diets can often increase margin over feed cost and net profit, even though feed cost per lb of gain is often increased. Using the response described above, we have modeled the impact of increasing energy density on net return and feed cost using actual prices paid for corn, soybean meal, and fat by one Midwestern production system over the last 5 years. The net return to added fat is almost always positive in lighter weight pigs (70 to 120 lb, Figure 4). However, the net return to added fat fluctuates for heavier weight pigs (230 to 265 lb, Figure 5). Adding fat to diets of lighter weight pigs increased feed cost per unit of gain 50% of the time and decreased it about 50% of the time (Figure 6). However, in heavier weight pigs, adding fat increased feed cost per unit of gain in most scenarios. This would tend to indicate that using high energy diets for lighter weight pigs are cost effective and increase profit the majority of the time. However, the optimal energy density of late finishing pig diets will depend on the economic conditions at the time and the importance of ADG to the production system. If ADG is not important, feed cost per pound of gain will dictate the optimal dietary energy density. If ADG is important, the value of the ADG must be included making net return the more important criterion in determining the optimal dietary energy density.

Table 1. Prediction Equations to Determine ADFI, and the Response in ADG and F/G to Added Fat in Growing-finishing Pig Diets

Response (Y)	Location	Equation
ADFI % BW	Field	Y = -0.0109 × BW, lb + 4.948
	University	Y = -0.0098 × BW, lb + 5.374
% ADG change per % added fat	Field	Y = 1.097 – 0.0009 × BW, lb × ADFI% BW – 0.0173 × fat level, %
	University	Y= 1.586 – 0.0009 × BW, lb × ADFI% BW – 0.1429 × fat level, %
% F/G change per % added fat	Field	Y = -2.9217 + 0.0017 × BW, lb × ADFI% BW + 0.0967 × fat level, %
	University	Y = -1.8851 + 0.0017 × BW, lb × ADFI% BW + 0.0306 × fat level, %

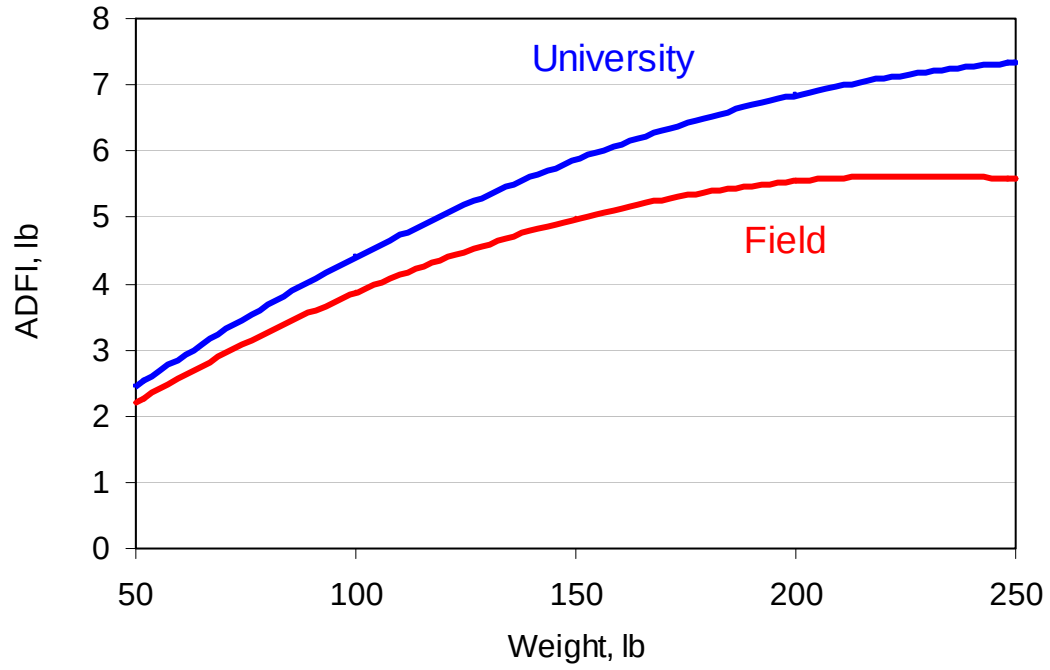

Figure 1. The Influence of Location on Average Daily Feed Intake.

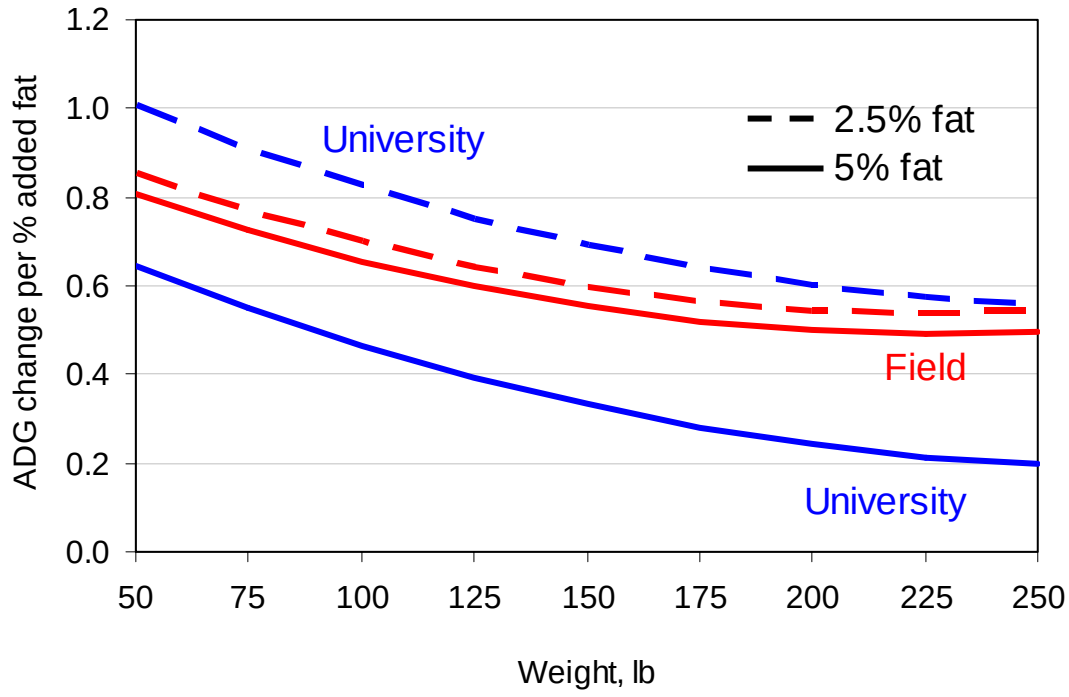

Figure 2. Impact of Study Location on ADG Response to Increased Energy Density by Adding Fat to a Corn Soybean Meal Diet.

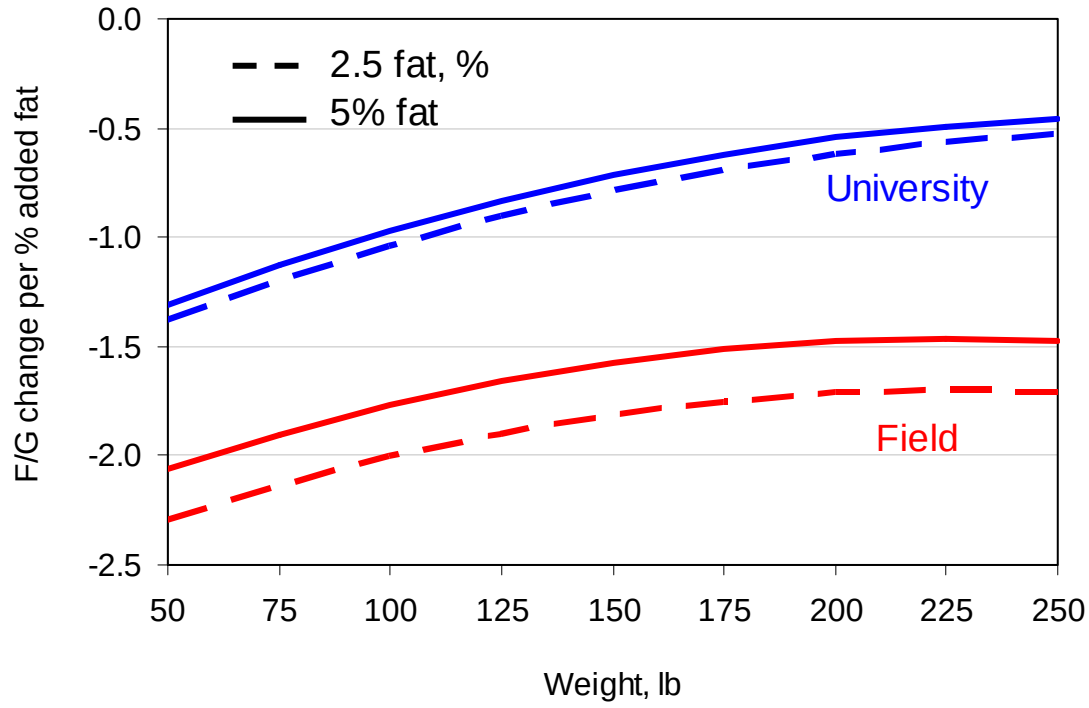

Figure 3. Impact of Study Location on F/G Response to Increased Energy Density by Adding Fat to a Corn Soybean Meal Diet.

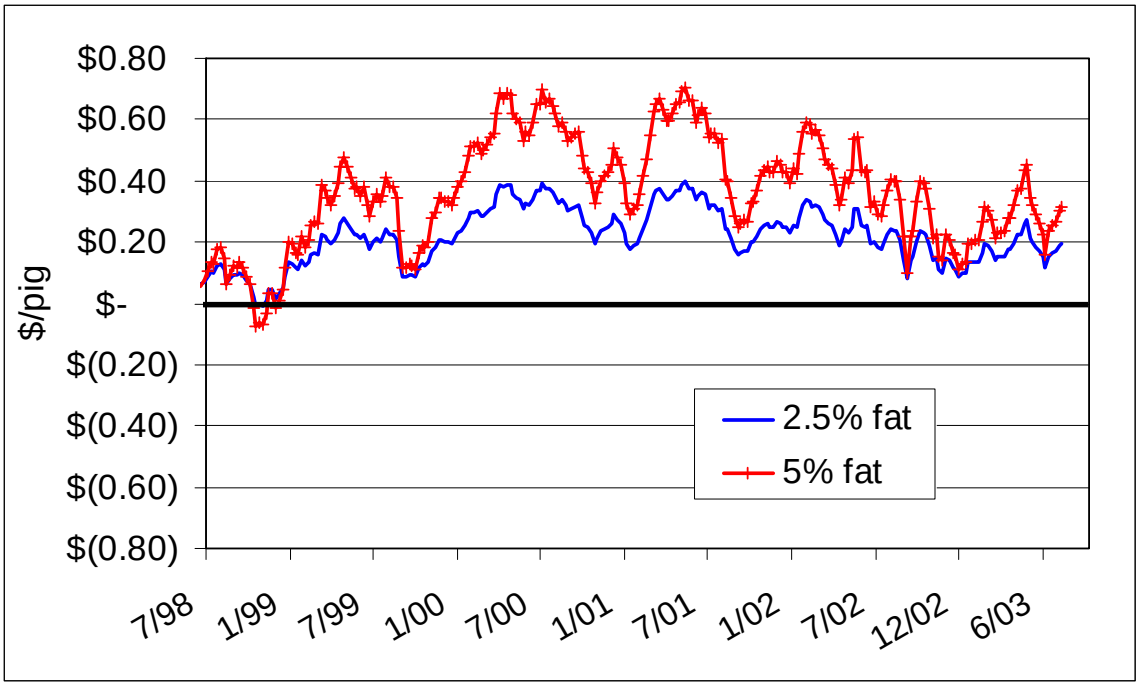

Figure 4. Net Return per Pig to Fat Addition from 70 to 120 lb.

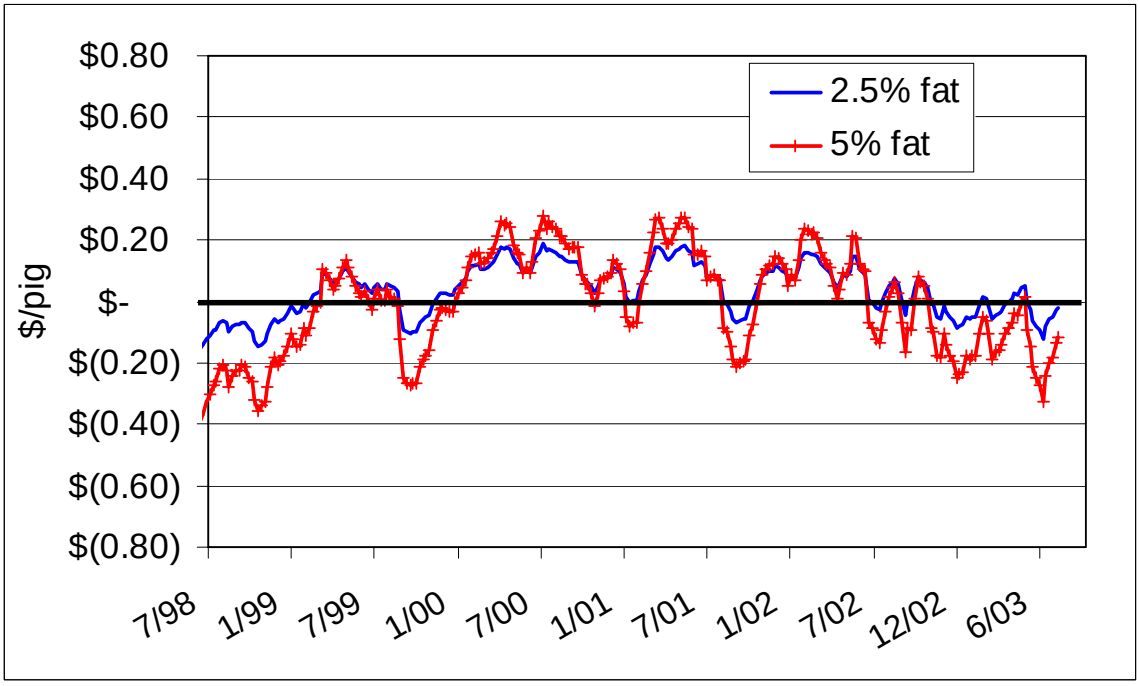

Figure 5. Net Return per Pig to Fat Addition from 230 to 265 lb.

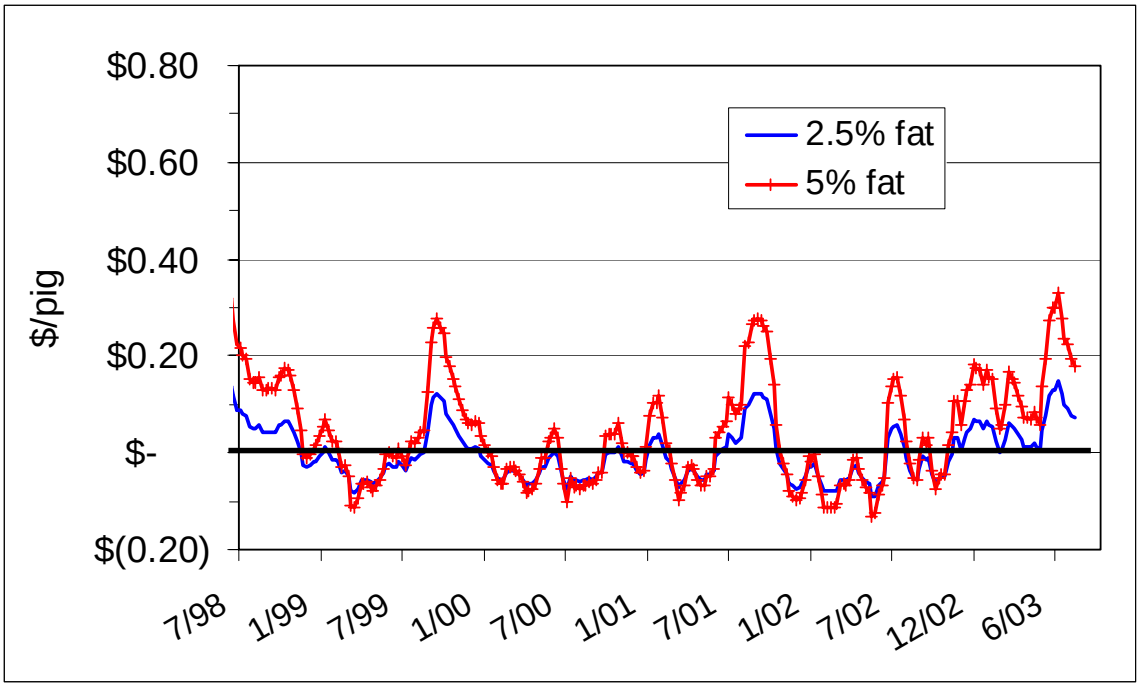

Figure 6. Increase in Feed Cost to Fat Addition from 70 to 120 lb.

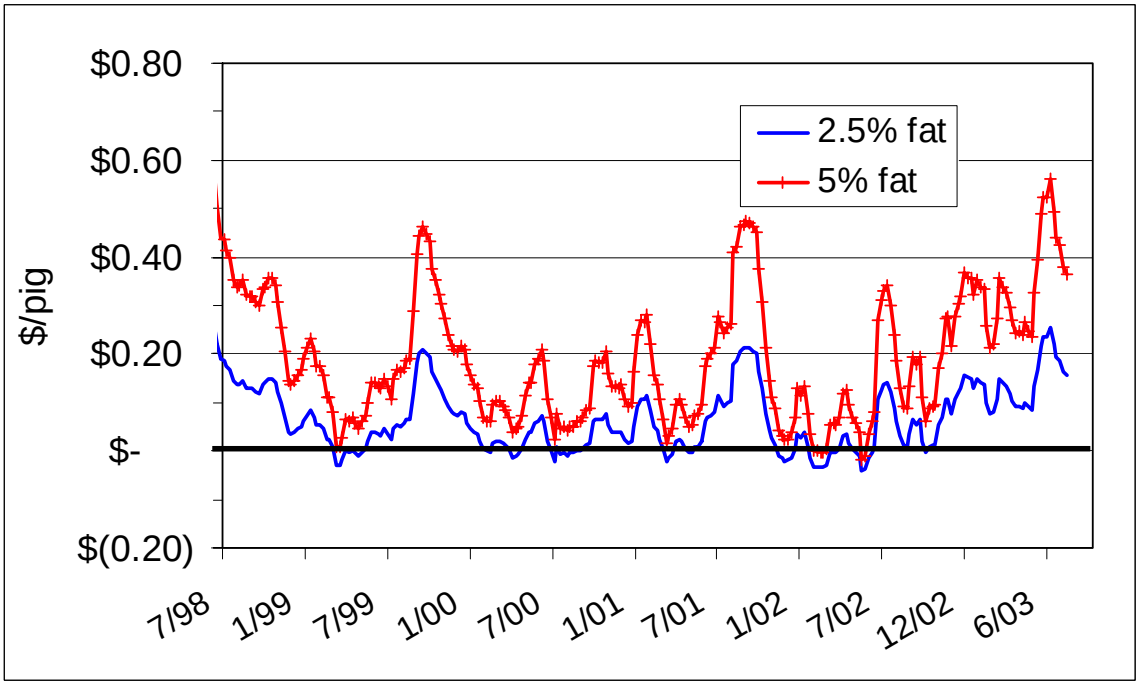

Figure 7. Increase in Feed Cost to Fat Addition from 230 to 265 lb.

Swine Day 2003

EFFECTS OF INCREASING CA:P RATIO IN DIETS CONTAINING PHYTASE ON FINISHING PIG GROWTH PERFORMANCE

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Summary

A total of 144 finishing pigs (72 barrows and 72 gilts, initially 85 lb) were used to determine the effects of calcium to total phosphorus (Ca:P) ratio in diets containing phytase on growth performance, carcass characteristics, and bone ash percentage. Pigs were housed in an environmentally regulated finishing building with two pigs per pen and six pens per sex per treatment in a randomized complete block design. Pigs were blocked by initial weight and sex, and then allotted to one of six dietary treatments.

The dietary treatments were corn-soybean meal-based diets fed in three phases. In each phase, diets consisted of a 0.75:1; 1:1; 1.25:1; 1.5:1, and 2:1 Ca:P ratio. A sixth treatment group was a diet containing 77% of the total P as the other treatment diets. Diets were formulated to contain 0.44%, 0.39%, and 0.34% total phosphorus and 0.15%, 0.12%, and 0.07% available phosphorus from d 0 to 28, 28 to 57, and 57 to 76, respectively. All diets contained 0.05% phytase, providing 300 FTU/kg in order to achieve equivalent available phosphorus values of 0.23%, 0.19%, and 0.15%. For the overall experiment, increasing Ca:P ratio decreased (linear, $P<0.03$) ADG and F/G. However, the greatest decrease in ADG and F/G was observed when Ca:P ratio increased from 1.5:1 to 2:1. Daily feed intake was not affected by Ca:P ratio. There was no difference in backfat thickness for pigs fed Ca:P ratios between 0.75:1 and 2.0:1 ($P<0.17$). However, pigs fed the negative control diet had reduced backfat thickness ($P<0.05$) compared to the other pigs. Bone ash percentage was not affected ($P<0.23$) by Ca:P ratio. These results suggest that in finishing diets containing 300 FTU/kg phytase, a Ca:P ratio greater then 1.5:1 will decrease ADG and ADFI.

(Key Words: Calcium, Phosphorus, Phytase, Finishing Pigs)

Introduction

Phytase releases phytic phosphorus from plant-based feedstuffs, which increases dietary P absorption and utilization and reduces the need for inorganic phosphorus supplementation. It has been widely demonstrated that dietary supplementation with phytase is effective in making phytate-bound P nutritionally available to growing pigs. Supplemental phytase in swine diets has resulted in improved growth performance and bone mineralization by increasing digestibility and retention of P and Ca. Because phytase use reduces P excretion and the levels of P in the environment, its use has been more widespread.

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[1]Food Animal Health and Management Center.

When formulating diets with phytase, the reduction in P results in a widening of the Ca:P ratio if the amount of limestone that is generally added is not also adjusted. Other research has shown that high dietary Ca concentrations increase the formation of an insoluble Ca-phytate complex and/or the reduction of phytase activity. Research conducted using weanling pigs showed that narrowing the dietary Ca:tP ratio from 2.0:1 to 1.2:1 led to an approximate 16% increase in phytase efficacy, thus, improving performance, digestibility, bone measurements, and serum Ca levels. It has also been demonstrated that growth performance and P utilization were increased by lowering the Ca:tP ratio from 1.5:1 to 1.0:1 in low-P corn-soybean meal diets supplemented with microbial phytase in grow-finish pigs.

Therefore our objective was to determine the optimum calcium to total phosphorus ratio in diets containing phytase on growth performance, carcass characteristics, and bone ash percentage in finishing pigs.

Procedures

One hundred forty-four pigs (72 barrows and 72 gilts; PIC 327 × C22) averaging 85 lb were used in this study. Pigs were housed in an environmentally regulated finishing building with two pigs per pen and twelve pens (5 × 5ft) per sex per treatment (six pens of barrows and six pens of gilts) in a randomized complete block design. Pigs were blocked by initial weight and sex, and then randomly allotted to one of the six dietary treatments. Feed and water were provided ad libitum.

The six dietary treatments consisted of calcium to total phosphorus ratios of 0.75:1; 1:1; 1.25:1; 1.5:1, and 2:1. A sixth treatment group was formulated to contain 77% of the total P of the other treatment diets and was the negative control in this study. Soybean meal, vitamin premixes, antibiotic, Natuphos 600, monocalcium phosphate, trace mineral premix, and limestone were analyzed for percentage calcium and phosphorus. These values were then used in diet formulation. Diets were fed in meal form in three phases, 28, 28, and 19 days in length, respectively, that corresponded to approximately 70 to 130 lb, 130 to 190 lb, and 190 to 250 lb, respectively. The same Ca:P ratios were used in each phase. Diets were formulated to contain 1.10%, 0.90%, and 0.75% total dietary lysine, and 0.44%, 0.39%, and 0.32% total phosphorus (0.15, 0.11, and 0.07 calculated available P) for phases 1, 2, and 3, respectively. The negative control diet was formulated to contain 0.39%, 0.33%, and 0.30% total P which corresponded to 0.11%, 0.07%, and 0.05% available phosphorus. Natuphos was added to all diets to provide 300 FTU/kg in order to achieve equivalent available phosphorus values of 0.23%, 0.19%, and 0.15% for phases 1, 2, and 3, respectively. Diets were analyzed for dry matter, crude protein, calcium, and phosphorus.

Individual pig weights were taken and feed disappearance were measured every 14 d to calculate ADG, ADFI, and F/G. At the end of the study, pigs were marked with an individual tattoo to allow for individual carcass data to be collected at marketing. All pigs were sent to Downs, Kansas, for individual carcass data collection (i.e., carcass weight and backfat thickness). The experiment was conducted from December to February.

Results and Discussion

From d 0 to 28, increasing Ca:P ratio decreased (linear, $P<0.001$), ADG and F/G, but did not affect ($P>0.82$) ADFI. The greatest decrease in performance was observed when the Ca:P ratio increased from 1.5:1 to 2.0:1. There was no difference between pigs fed the negative control and the mean of all other Ca:P ratio treatments for either ADG, ADFI, and F/G. In addition, barrows had greater ($P<0.001$), ADG, and ADFI compared to gilts, but F/G was not affected ($P>0.91$). From d 28

to 57, increasing the Ca:P ratio decreased (quadratic, P<0.04) ADG and F/G, but did not affect ADFI (P>0.14). Again, like d 0 to 28, the greatest change in performance was observed when Ca:P ratio increased from 1.5:1 to 2.0:1. Barrows had greater (P<0.0001), ADG and ADFI then gilts, with no difference (P>0.15) in feed efficiency. There were no differences between pigs fed the negative control and the other diets for ADG, ADFI, and F/G. From d 57 to 76 increasing the Ca:P ratio decreased ADFI (quadratic, P<0.02) but, did not affect (P>0.13), ADG and F/G. As in d 0 to 28 and 28 to 57 there were no differences between pigs fed the negative control and the mean of the other Ca:P ratios for either ADG, ADFI, and F/G. Barrows had greater (P<0.05), ADG and ADFI than gilts, while gilts had improved F/G (P<0.01) compared to barrows.

For the overall study, increasing the Ca:P ratio decreased (linear, P<0.003), ADG and F/G, with no affect on ADFI (P>0.42). Similar to the response in both phase 1 and 2, the greatest changes in ADG and F/G occurred when the Ca:P ratio increased from 1.5:1 to 2.0:1. As in each of the growth periods there were no differences between pigs fed the negative control and the mean of the other Ca:P ratio treatments for ADG, ADFI, or F/G. Furthermore, barrows had a greater (P<0.001), ADG and ADFI than the gilts, while the gilts had an improved F/G (P<0.03) compared to the barrows.

Increasing the Ca:P ratio decreased the final live animal weight (linear, P<0.003) but, did not affect carcass weight (P<0.11). Also, barrows had higher (P<0.05) carcass weight and backfat thickness compared to gilts. There was no difference in backfat thickness for pigs fed Ca:P ratios between 0.75:1 and 2.0:1 (P<0.17). However, pigs fed the negative control had reduced backfat thickness (P<0.05) compared to the other pigs. In addition bone ash percentage was not affected (P<0.23) by Ca:P ratio or gender.

When comparing pigs fed the negative control to the mean of the other Ca:P ratio treatments, there are no differences, due mostly to the low values of pigs fed the 2:1 Ca:P ratio. However, throughout the study, ADG and F/G of pigs fed the negative control diets are numerically poorer than pigs fed the optimal Ca:P ratios (1.25:1 and below). The negative control treatment was included in the experiment to ensure our dietary phosphorus levels were not above the pig's requirement. If we were well above the pigs requirement for phosphorus in our diets this would affect our interpretation.

In conclusion, these results suggest that increasing the calcium to total phosphorus ratio above a 1.5:1 ratio in a corn-soybean meal-based diet containing 300 FTU/kg phytase for growing finishing pigs can have a negative effect on growth performance, carcass traits, and bone ash percentage.

Table 1. Diet Composition (As-fed Basis)

Ingredient, %	Day 0 to 28	Day 28 to 56	Day 56 to 73
Corn	69.99	77.80	83.67
Soybean meal, 46.5% CP	26.51	19.18	13.72
Monocalcium phosphate, 21% P	0.40	0.25	0.10
Limestone	0.38 – 1.99	0.36 – 1.74	0.35 – 1.53
Salt	0.35	0.35	0.35
Vitamin premix	0.15	0.15	0.15
Trace mineral premix	0.15	0.15	0.15
Medication[a]	0.05	0.05	0.05
Sand	1.71 – 0.21	1.39 – 0.31`	1.08 – 0.08
Lysine HCL	0.15	0.15	0.15
Phytase[b]	0.05	0.05	0.05
Calculated analysis			
Lysine, %	1.10	0.90	0.75
Protein, %	18.30	15.50	13.50
ME, Kcal/lb	1,492	1,501	1,509
Ca, %	0.33 – 0.88	0.28 – 0.75	0.24 – 0.64
P, %	0.44	0.38	0.32
Available P, %	0.15	0.11	0.07

[a]Provided 44 mg/kg of Tylosin.
[b]Provided 300 FTU/kg of feed (Natuphos® 600).

Table 2. Influence of Calcium to Total Phosphorus Ratio on Growth Performance and Bone Ash in Finishing Pigs[a]

	Calcium:Phosphorus ratio							Probability (P<)			Sex		
Item	Neg control	0.75:1	1:1	1.25:1	1.5:1	2:1	SED	Linear	Quad	Neg vs others	Barrows	Gilts	P< Value
Day 0 to 28													
ADG, lb	2.17[b]	2.31[c]	2.25[bc]	2.23[bc]	2.14[bd]	2.03[d]	0.06	0.001	0.69	0.66	2.31	2.07	0.001
ADFI, lb	5.24	5.22	5.15	5.17	5.05	5.20	0.14	0.82	0.28	0.47	5.45	4.89	0.001
F/G	2.41[b]	2.26[c]	2.30[bc]	2.33[bc]	2.36[bc]	2.58	0.07	0.001	0.16	0.41	2.37	2.38	0.77
Day 28 to 57													
ADG, lb	2.32[bc]	2.56[bc]	2.42[b]	2.37[bc]	2.35[bc]	21.8[c]	0.10	0.19	0.04	0.98	2.44	2.19	0.001
ADFI, lb	7.03	6.76	6.46	6.66	6.55	7.00	0.29	0.26	0.14	0.13	7.20	6.28	0.001
F/G	3.05[bc]	3.00[bc]	2.68[a]	2.83[ab]	2.80[ab]	3.22[c]	0.13	0.01	0.001	0.16	2.97	2.89	0.29
Day 57 to 76													
ADG, lb	1.79	1.86	1.98	1.92	1.96	1.79	0.12	0.41	0.15	0.21	1.95	1.82	0.053
ADFI, lb	7.05[b]	6.99[bc]	7.52[bc]	7.65[d]	7.42[bcd]	7.24[bcd]	0.26	0.70	0.02	0.13	7.82	6.80	0.001
F/G	3.98	3.83	3.86	4.07	3.82	4.11	0.21	0.24	0.86	0.78	4.08	3.81	0.03
Overall													
ADG, lb	2.14[bc]	2.19[c]	2.25[c]	2.21[c]	2.18[c]	2.03[b]	0.06	0.003	0.04	0.45	2.28	2.06	0.001
ADFI, lb	6.35	6.22	6.20	6.31	6.17	6.37	0.15	0.42	0.66	0.50	6.67	5.87	0.001
F/G	2.97[b]	2.84[bc]	2.75[c]	2.85[bc]	2.83[c]	3.15[d]	0.07	0.001	0.001	0.10	2.94	2.86	0.05
Live wt.	241.0[bc]	2.44.0[c]	249.5[c]	246.5[c]	244.1[c]	233.3[b]	4.46	0.003	0.03	0.48	251.8	234.3	0.001
Packing Plant Data													
Carcass wt., lb	188.6	190.7	188.8	187.2	188.7	183.7	4.09	0.11	0.82	0.81	190.33	185.57	0.05
Backfat, in.	0.74[b]	0.83[bc]	0.83[bc]	0.89[bc]	0.90[bc]	0.93[c]	0.06	0.17	0.81	0.05	0.92	0.79	0.01
Bone ash, %													
3rd Metacarpal	43.30	43.22	41.19	43.33	42.77	42.96	0.008	0.64	0.95	0.75	43.19	43.06	0.79
4th Metacarpal	43.84	44.48	44.66	45.15	43.75	43.66	0.01	0.22	0.56	0.50	44.29	44.22	0.90
Average bone ash	43.57	43.85	43.93	44.24	43.26	43.31	0.007	0.23	0.71	0.77	43.74	43.64	0.79

[a]Values are means of 144 pigs (initially 85 lb) with 2 pigs per pen and 12 replicate pens per treatment.
[b,c,d]Means on the same row with different superscript differ (P<0.05).

EFFECTS OF CORN SOURCE AND FAT LEVEL ON GROWTH PERFORMANCE OF GROW-FINISH PIGS REARED IN A COMMERCIAL FACILITY[1]

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R.D. Goodband, J.M. DeRouchey, and C.L. Jones

Summary

A total of 1,144 gilts (initially 110.4 lb, PIC) was used in a commercial research facility to evaluate the effects of corn source (NutriDense™, BASF, or #2 Yellow Dent) and added fat (averaging 0, 3, and 6%) on pig performance and carcass traits. Energy levels were based such that the higher energy (assuming 5% greater ME than #2 yellow dent) in NutriDense corn (with or without added fat) was calculated to be equal to that provided by yellow dent corn and added fat. In each phase, the first treatment diet contained yellow dent corn and no added fat. In the next dietary treatment, yellow dent corn was replaced with NutriDense corn, and then fat was added (2.7 to 3.2% based on phase) to the yellow dent corn-based diet to equal the energy content of the NutriDense corn diet. This amount of added fat was then added to the NutriDense-based diet. The last yellow dent corn based diet used 5.2 to 6.2% (based on phase) added fat to equal the energy content of the second NutriDense corn diet. This amount of fat was then added to the NutriDense-base diet to complete the treatment structure.

For the overall study, pigs fed NutriDense corn had greater (P<0.04) ADG compared to pigs fed yellow dent corn. There was a corn source by fat level interaction (P<0.01) observed for ADFI and F/G. When fat was added to diets containing NutriDense corn, F/G decreased linearly, whereas when fat was added to yellow dent corn the greatest improvement in feed efficiency was observed with the first 3% added fat. Adding fat to diets also increased (P<0.01) final and carcass weight, and tended (P<0.09) to increase backfat thickness. Using the known energy values of yellow dent corn and fat, we calculated NutriDense corn to have 5.3% more ME than yellow dent corn.

These results are similar to previous research in nursery pigs at Kansas State University showing 5% more ME for NutriDense corn than yellow dent corn. This also supports work done the University of Illinois which determined that NutriDense corn has 6.5% more ME than yellow dent corn. Increasing the dietary energy level above a yellow dent corn-soybean meal-based diet with 6% added fat improved ADG and F/G in grow-finish pigs. Furthermore, pigs fed NutriDense corn had greater ADG than pigs fed yellow dent corn.

(Key Words: Corn, Fat, Energy, Grow-Finish Pigs)

Introduction

NutriDense corn is a nutritionally enhanced product containing a stacked set of traits to provide greater nutrient density than

[1]Appreciation is expressed to Exseed Genetics, a BASF company, for partial financial support for this trial.
[2]Food Animal Health and Management Center.

conventional yellow dent corn. Specifically, it contains approximately 30% more lysine, 50% more sulfur-containing amino acids, 18% more threonine, and almost 25% more tryptophan (Table 1). Feeding trials with nursery pigs at Kansas State University indicated that the energy value of NutriDense corn was approximately 5% greater than the energy density of yellow dent corn. In these trials, F/G was improved linearly through the highest level of energy (6% fat added to a diet containing NutriDense corn).

Past research trials conducted in commercial research facilities indicate that ADG and F/G improve linearly when increasing levels of fat are added to grow-finish diets. The purpose of this experiment was to validate the nursery trials and data from the University of Illinois that indicate NutriDense corn contains 5 to 6% more ME than yellow dent corn. The second objective was to determine if grow-finish pig performance continues to be improved linearly when dietary energy density is increased beyond the level achieved with yellow dent corn and added fat.

Procedures

This experiment was conducted in a commercial research facility. The barn was curtain sided, with total concrete slats over a deep pit. The barn operates on natural ventilation during the summer and mechanically assisted ventilation during the winter. This trial was started in January and ended in April 2003. Forty-two pens of gilts (PIC C22 X L337) were blocked by weight (initially 110.4 lb) and allotted to one of six dietary treatments. There were initially 27 or 28 pigs per pen and seven pens per treatment. Each pen was 10 × 18 ft, and contained one 4-hole dry feeder and one cup waterer. The experimental diets used were formulated with either Yellow Dent (YD) or NutriDense (ND) corn with increasing levels of choice white grease (Tables 2 to 4). The first treatment diet contained yellow dent corn and no added fat. In the next dietary treatment, yellow dent corn was replaced with NutriDense corn and then fat was added (2.7 to 3.2%, based on phase) to the yellow dent corn-based diet to equal the energy content of the NutriDense corn diet. This amount of added fat was then added to the NutriDense-based diet. The last yellow dent corn based diet used 5.2 to 6.2% (based on phase) added fat to equal the energy content of the second NutriDense corn diet. This amount of fat was then added to the NutriDense-base diet to complete the treatment structure.

All diets were formulated to maintain an equal lysine:calorie ratio and Ca:tP ratio within each phase. Corn dry matter values were 87.3 and 85.2% for ND and YD corn, respectively.

Pig weights and feed disappearance were measured every 14 d to calculate ADG, ADFI, and F/G. Diet phase changes occurred on d 14 and 42. At the end of the experiment, pigs in each pen were individually tattooed and transported to a commercial meat packing facility where carcass traits were obtained.

Analysis of variance was conducted on all data using the PROC MIXED procedure of SAS. Pen was used as the experimental unit of analysis for all treatment effects. The statistical model included treatment as a fixed effect and block as random effect.

Results and Discussion

For phase 1 (d 0 to 14), there were no ($P>0.21$) corn source by added fat interactions (Table 5). Corn source had no effect ($P>0.27$) on ADG or ADFI; however, pigs fed NutriDense corn had improved ($P<0.05$) F/G compared to pigs fed yellow dent corn. Increasing dietary fat increased (linear, $P<0.01$) ADG, reduced (quadratic, $P<0.01$) ADFI and improved (quadratic, $P<0.01$) F/G.

In phase 2 (d 14 to 42), pigs fed NutriDense had greater ($P<0.04$) ADG than pigs

fed yellow dent corn. Increasing added fat had no effect (P>0.51) on ADG. There was a corn source by added fat interaction for ADFI and F/G. For ADFI, the interaction appears to be the result of a greater rate of decrease in feed intake as fat increased in diets containing yellow dent corn, compared with the relatively smaller change in feed intake with added fat in diets containing NutriDense corn. The interaction in F/G appears to be the result of a linear improvement in F/G as fat increased in diets containing NutriDense corn, whereas the response to added fat in yellow dent corn was quadratic and maximized at 3%.

In phase 3 (d 42 to 78), corn source had no effect (P>0.37) on ADG; however increasing fat improved (linear, P<0.05) ADG. As in phase 2, there was a tendency (P<0.06) for a corn source by added fat interaction. Again the interaction appears to be the result of a greater rate of decrease in feed intake as fat was added in diets containing yellow dent corn compared to diets containing NutriDense corn. Feed efficiency was improved (linear, P<0.05) as added fat increased and tended (P<0.08) to be improved for pigs fed NutriDense corn compared to pigs fed yellow dent corn.

For the overall experiment period, pigs fed NutriDense corn had greater (P<0.04) ADG compared to pigs fed yellow dent corn. Increasing dietary fat increased (quadratic, P<0.08) ADG, with the greatest improvement observed as fat increased from 0 to 3%. Similar to the response in phase 2, there was a corn source by added fat interaction for ADFI and F/G. For ADFI, the interaction appears to be the result of a greater rate of decrease in feed intake as fat increased in diets containing yellow dent corn, compared with the relatively smaller change in feed intake with added fat in diets containing NutriDense corn. The interaction in F/G appears to be the result of a linear improvement in F/G as fat increased in diets containing NutriDense corn, whereas the response to added fat in yellow dent corn was quadratic, with the greatest response to the first 3% added fat.

To determine the energy concentration in NutriDense corn, we looked at the energetic efficiency of gain. Pigs fed diets with NutriDense corn (assumed to contain 5% more ME) had similar energetic efficiency to pigs fed yellow dent corn diets with similar dietary ME. By comparing the energetic efficiency between corn sources formulated to the same energy density, data suggest that pigs fed NutriDense corn have almost exactly the same energetic efficiency when we assume a 5% greater ME value for NutriDense corn.

We also calculated an energy efficiency ratio by dividing the calculated ME intake by lb of gain. For this calculation, we used NRC (1998) ME values for yellow dent corn, soybean meal, and fat. Assuming that the energetic efficiency of gain within the three levels of added fat should be similar, we could then extrapolate the ME content of NutriDense corn compared to yellow dent corn. Using this procedure, the average ME value of NutriDense corn is 1,634 kcal/lb or 5.3% greater than that of yellow dent corn.

There were no differences (P>0.18) in carcass weight, backfat depth, loin depth, and percentage muscle, and fat-free lean index among pigs fed either NutriDense or yellow dent corn. However, pigs fed yellow dent corn had greater (P<0.05) yield percentage than those fed NutriDense corn. Increasing added fat increased (P<0.01) carcass weight, but had no effect (P>0.18) on percentage yield, muscle, or fat free lean index.

We calculated the economic value of NutriDense corn compared to yellow dent corn. We compared diets formulated to contain identical energy, lysine, and phosphorus concentrations with either NutriDense or yellow dent corn. We used a value of $2.24/bu for yellow dent corn, $180/ton for soybean meal $290/ton for monocalcium phosphorus,

$40/ton for limestone, and $240/ton for choice white grease in our calculations. Using the difference in diet cost and amount of corn in the diets, we calculated the extra value provided by using NutriDense corn. The economic comparison indicates producers can pay up to $0.13/bu premium for ND corn to realize the same growth performance benefits of a YD corn diet with added soybean meal and choice white grease.

In conclusion, our results are similar to previous research in nursery pigs at Kansas State University showing that NutriDense corn contains approximately 5% more ME than yellow dent corn. This agrees with data from the University of Illinois, which show that NutriDense corn has 6.5% more ME than yellow dent corn. The results of our study also show that increasing the dietary energy level above a corn-soybean meal-added fat diet with NutriDense corn improves ADG and F/G in grow-finish pigs. In summary, the use of NutriDense corn in grow-finish diets provides an opportunity to achieve higher dietary ME levels and improved growth performance compared to diets containing yellow dent corn.

Table 1. Composition of Corn Sources[a]

Item	Yellow Dent	NutriDense
Dry matter, %	89 (85.21)	88 (87.39)
Either extract, %	3.9 (3.48)	4.8 (4.56)
Protein, %	8.3 (7.39)	10 (9.33)
ME, kcal/lb	1,551	1,629
Crude Fiber, %	2.8 (2.38)	2.0 (2.26)
Ca, %	0.03 (0.02)	0.01 (0.06)
P (Total), %	0.28 (0.24)	0.32 (0.28)
P (Available), %	0.14	0.11
Mg, %	0.12 (0.10)	0.13 (0.11)
K, %	0.33 (0.32)	0.35 (0.32)
S, %	0.13	0.11
Amino acids, %		
Lysine	0.26 (0.23)	0.31 (0.28)
Arginine	0.37 (0.36)	0.52 (0.46)
Cystine	0.19 (0.19)	0.23 (0.24)
Isoleucine	0.28 (0.26)	0.41 (0.35)
Leucine	0.99 (0.92)	1.25 (1.25)
Methionine	0.17 (0.16)	0.21 (0.22)
Tryptophan	0.06 (0.06)	0.08 (0.07)
Threonine	0.29 (0.27)	0.34 (0.33)
Valine	0.39 (0.38)	0.55 (0.47)

[a]Values represent estimated composition from NRC, 1998 for yellow dent corn and NutriDense corn provided by BASF used in diet formulation. Values in ( ) represent actual analyzed chemical composition.

Table 2. Composition of Phase 1 Experimental Diets (As-fed Basis)[a]

Corn Source:	Yellow Dent			NutriDense		
Ingredient, % Fat level:	0	2.7	5.2	0	2.7	5.2
Yellow dent corn	68.65	64.09	59.98			
NutriDense corn				68.41	63.92	59.87
Soybean meal, 46.5% CP	28.60	30.41	31.99	28.91	30.66	32.17
Choice white grease		2.70	5.20		2.70	5.20
Monocalcium phosphate, 21% P	1.13	1.18	1.21	0.96	1.01	1.07
Limestone	0.95	0.95	0.95	1.05	1.04	1.03
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix with phytase	0.08	0.08	0.08	0.08	0.08	0.08
Trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10
Lysine HCl	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis						
Lysine, %	1.16	1.20	1.24	1.20	1.24	1.28
Lysine:calorie ratio, g/mcal	3.50	3.50	3.50	3.50	3.50	3.50
Isoleucine:lysine ratio, %	0.67	0.67	0.67	0.75	0.74	0.74
Leucine:lysine ratio, %	1.49	1.45	1.42	1.59	1.55	1.51
Methionine:lysine ratio, %	0.27	0.26	0.26	0.28	0.27	0.27
Met & Cys:lysine ratio, %	0.56	0.55	0.54	0.60	0.58	0.57
Threonine:lysine ratio, %	0.63	0.62	0.62	0.64	0.63	0.63
Tryptophan:lysine ratio, %	0.20	0.20	0.20	0.20	0.20	0.20
Valine:lysine ratio, %	0.79	0.78	0.77	0.86	0.84	0.83
ME, kcal/lb	1,504	1,558	1,609	1,558	1,609	1,656
Protein, %	19.13	19.59	19.97	20.28	20.65	20.95
Ca, %	0.69	0.70	0.71	0.68	0.69	0.70
P, %	0.63	0.64	0.64	0.62	0.63	0.64
Ca: tP Ratio	1.10	1.10	1.10	1.10	1.10	1.10
Available P, %	0.31	0.32	0.32	0.33	0.33	0.34

[a]Diets fed from d 0 to 14.

Table 3. Composition of Phase 2 Experimental Diets (As-fed Basis)[a]

Corn Source:	Yellow Dent			NutriDense		
Ingredient, % Fat level:	0	2.7	5.2	0	2.7	5.2
Yellow dent corn	68.65	64.09	59.98			
NutriDense corn				68.41	63.92	59.87
Soybean meal, 46.5% CP	28.60	30.41	31.99	28.91	30.66	32.17
Choice white grease		2.70	5.20		2.70	5.20
Monocalcium phosphate, 21% P	1.13	1.18	1.21	0.96	1.01	1.07
Limestone	0.95	0.95	0.95	1.05	1.04	1.03
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix with phytase	0.08	0.08	0.08	0.08	0.08	0.08
Trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10
Lysine HCl	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis:						
Lysine, %	0.97	1.00	1.04	1.00	1.04	1.08
Lysine:calorie ratio, g/mcal	2.90	2.90	2.90	2.90	2.90	2.91
Isoleucine:lysine ratio, %	0.66	0.66	0.66	0.77	0.76	0.75
Leucine:lysine ratio, %	1.60	1.55	1.51	1.73	1.67	1.62
Methionine:lysine ratio, %	0.28	0.28	0.27	0.30	0.29	0.29
Met & Cys:lysine ratio, %	0.60	0.58	0.57	0.65	0.63	0.61
Threonine:lysine ratio, %	0.64	0.63	0.63	0.65	0.65	0.64
Tryptophan:lysine ratio, %	0.19	0.19	0.19	0.19	0.19	0.19
Valine:lysine ratio, %	0.81	0.80	0.79	0.90	0.88	0.87
ME, kcal/lb	1,509	1,569	1,625	1,569	1,625	1,679
Protein, %	16.46	16.85	17.21	17.59	17.93	18.24
Ca, %	0.61	0.62	0.63	0.60	0.61	0.62
P, %	0.55	0.56	0.57	0.54	0.55	0.56
Ca: tP Ratio	1.10	1.10	1.10	1.10	1.10	1.10
Available P, %	0.26	0.27	0.28	0.27	0.27	0.29

[a]Diets fed from d 14 to 42.

Table 4. Composition of Phase 3 Experimental Diets (As-fed Basis)[a]

Corn Source	Yellow Dent			NutriDense		
Ingredient, % Fat level:	0	3.2	6.2	0	3.2	6.2
Yellow dent corn	80.99	76.16	71.69			
NutriDense corn				81.28	76.49	72.01
Soybean meal, 46.5%	16.98	18.59	20.03	16.80	18.35	19.81
Choice white grease		3.20	6.20		3.20	6.20
Monocalcium Phosphate, 21% P	0.59	0.63	0.67	0.37	0.43	0.47
Limestone	0.85	0.84	0.82	0.96	0.94	0.93
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix with phytase	0.06	0.06	0.06	0.06	0.06	0.06
Trace mineral premix	0.08	0.08	0.08	0.08	0.08	0.08
Lysine HCl	0.10	0.10	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis:						
Lysine, %	0.80	0.84	0.87	0.84	0.87	0.90
Lysine:calorie ratio, g/mcal	2.40	2.40	2.40	2.40	2.40	2.40
Isoleucine:lysine ratio, %	0.69	0.69	0.69	0.83	0.82	0.80
Leucine:lysine ratio, %	1.77	1.71	1.66	1.95	1.87	1.81
Methionine:lysine ratio, %	0.31	0.30	0.29	0.34	0.33	0.32
Met & Cys:lysine ratio, %	0.66	0.64	0.62	0.73	0.70	0.68
Threonine:lysine ratio, %	0.68	0.67	0.66	0.70	0.69	0.68
Tryptophan:lysine ratio, %	0.20	0.20	0.20	0.20	0.20	0.20
Valine:lysine ratio, %	0.87	0.86	0.84	0.99	0.96	0.94
ME, kcal/lb	1,517	1,582	1,643	1,582	1,643	1,701
Protein, %	14.78	15.12	15.41	15.94	16.18	16.41
Ca, %	0.51	0.52	0.52	0.50	0.51	0.51
P, %	0.47	0.47	0.48	0.45	0.46	0.47
Ca: tP Ratio	1.10	1.10	1.10	1.10	1.10	1.10
Available P, %	0.18	0.19	0.20	0.19	0.20	0.21

[a]Diet fed from d 42 to 78.

Table 5. Effects of Corn Source and Added Fat on Growth Performance of Grow-Finish Pigs in a Commercial Facility[a]

	Yellow Dent			NutriDense			Probability P <				Fat Level, %			Probability P<			Corn Source		
Item, Fat %[b]	0	3	6	0	3	6	Level	Source	Level x Source	SE	0	3	6	Linear	Quad	SE	YD	ND	SE
Phase 1[c]																			
ADG, lb	1.84	1.96	1.99	1.93	1.94	2.02	0.01	0.27	0.21	0.054	1.88	1.95	2.01	0.01	0.76	0.049	1.96	1.93	0.047
ADFI, lb	4.11	4.00	4.01	4.15	3.89	3.96	0.01	0.35	0.36	0.032	4.13	3.94	3.98	0.01	0.02	0.041	4.04	4.00	0.034
F/G	2.24	2.04	2.01	2.16	2.00	1.96	0.01	0.05	0.80	0.032	2.20	2.02	1.99	0.01	0.01	0.023	2.10	2.04	0.018
Phase 2[d]																			
ADG, lb	1.95	1.98	1.91	1.98	1.99	2.00	0.51	0.04	0.28	0.040	1.96	1.98	1.96	0.84	0.26	0.035	1.94	1.99	0.033
ADFI, lb	5.36	4.95	4.74	4.90	4.81	4.75	0.01	0.01	0.02	0.131	5.13	4.88	4.75	0.01	0.40	0.116	5.02	4.82	0.110
F/G	2.76	2.50	2.49	2.48	2.42	2.37	0.01	<0.01	0.05	0.048	2.62	2.46	2.43	0.01	0.09	0.038	2.58	2.43	0.033
Phase 3[e]																			
ADG, lb	1.66	1.75	1.69	1.66	1.73	1.77	0.05	0.37	0.32	0.034	1.66	1.74	1.73	0.05	0.13	0.024	1.70	1.72	0.020
ADFI, lb	5.43	5.19	4.90	5.19	5.17	5.00	0.01	0.31	0.06	0.112	5.31	5.18	4.96	0.01	0.45	0.099	5.18	5.12	0.094
F/G	3.28	2.98	2.91	3.13	2.99	2.84	0.01	0.08	0.25	0.051	3.21	2.98	2.87	0.01	0.16	0.040	3.06	2.99	0.035
Overall																			
ADG, lb	1.80	1.87	1.83	1.83	1.87	1.90	0.01	0.04	0.13	0.021	1.81	1.87	1.86	0.01	0.08	0.017	1.83	1.86	0.015
ADFI, lb	5.15	4.87	4.67	4.88	4.79	4.71	0.01	0.01	0.01	0.072	5.02	4.83	4.69	0.01	0.55	0.046	4.90	4.79	0.059
F/G	2.87	2.60	2.56	2.67	2.57	2.49	0.01	0.01	0.01	0.033	2.77	2.59	2.52	0.01	0.01	0.024	2.68	2.52	0.026
Energy Efficiency[f]	4,335	4,097	4,197	4,216	4,196	4,185	0.01	0.97	0.03	47.4	4,276	4,147	4,177	0.02	0.03	38.2	4,201	4,199	34.6

[a]A total of 1,144 pigs (27 or 28 pigs per pen and 7 pens per treatment) with and average initial BW of 110.4 lbs. [b]Actual fat used in diets was 0, 2.7, 5.2 for phases 1 and 2, and 0, 3.2 and 6.2 for phase 3. [c]Phase 1 diets fed d 0 to 14; Lysine:Calorie 3.50; Ca:tP 1.10; AveP:ME 0.93. [d]Phase 2 diets fed d 14 to 42; Lysine:Calorie 2.90; Ca:tP 1.10; AveP:ME 0.77. [e]Phase 3 diets fed d 42 to 78; Lysine:Calorie 2.40; Ca:tP 1.10; AveP:ME 0.55 . [f]Calculated as energy required per kg of gain (kcal ME/lb of gain) using ME values of 1,551 for corn, 1,533 for soybean meal, 3,608 for fat, and 1,629 for NutriDense corn.

Table 6. Effects of Corn Source and Levels of Fat on Carcass Traits of Grow-Finish Pigs in a Commercial Facility

	Yellow Dent			NutriDense			Probability P <				Fat Level, %			Probability P <			Corn Source		
Item, Fat %[a]	0	3	6	0	3	6	Level	Source	Level x Source	SE	0	3	6	Linear	Quad.	SE	YD	ND	SE
Final wt, lb	251.03	256.42	254.96	252.53	257.57	257.89	0.01	0.140	0.82	2.305	251.78	256.99	256.42	0.01	0.03	2.049	254.13	256.00	1.956
Carcass wt, lb	190.12	194.01	191.19	189.75	192.74	194.55	0.01	0.51	0.11	1.744	189.93	193.37	192.87	0.01	0.04	1.573	192.35	191.77	1.509
Yield	75.52	75.61	74.85	75.03	74.85	74.73	0.19	0.05	0.51	0.003	75.27	75.23	74.79	0.09	0.39	0.002	75.33	74.87	0.002
Backfat[b]	0.58	0.60	0.61	0.58	0.60	0.59	0.28	0.65	0.64	0.013	0.58	0.60	0.60	0.22	0.32	0.009	0.60	0.59	0.007
Loin depth[b]	2.20	2.21	2.19	2.17	2.16	2.17	0.97	0.13	0.94	0.038	2.19	2.18	2.18	0.84	0.97	0.019	2.20	2.17	0.016
Lean, %[b]	56.55	56.35	56.18	56.50	56.08	56.37	0.33	0.81	0.58	0.221	56.56	56.19	56.26	0.28	0.32	0.150	56.36	56.31	0.123
FFLI[b]	51.03	50.92	50.83	51.11	50.83	51.06	0.42	0.55	0.59	0.149	51.07	50.88	50.95	0.42	0.31	0.105	50.93	51.00	0.083

[a]Actual fat used in diets was 0, 2.7, 5.2 for phases 1 and 2, and 0, 3.2 and 6.2 for phase 3.
[b]Carcass weight was used as a covariate in analysis.

USE OF DRIED DISTILLER'S GRAINS WITH SOLUBLES FOR SWINE DIETS

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Summary

A large increase in the number of ethanol plants has lead to increased availability of dried distiller's grains with solubles (DDGS). New plants also have improved processing techniques, which makes DDGS more attractive to use in swine diets.

Two experiments were conducted to determine the energy value of DDGS. In Experiment 1, 360 pigs (each initially 38.5 lb) were used in a 22 d growth assay. Treatments consisted of five corn-soybean meal-based diets with added wheat bran or soy oil to provide five different energy densities ranging from 1,390 to 1,604 Kcal/lb ME. The objective was to use responses to the wide range of energy densities to calculate an energy value for two sources of DDGS.

Because it is speculated that newer ethanol plants produce a better quality DDGS than older plants, we selected one relatively new plant in Minnesota, and a second, older plant in Nebraska as separate sources of DDGS. Pigs were fed four additional diets, including either 15 or 30% DDGS from one of the two different sources. For the overall 22 d study, increasing energy increased ADG (linear; $P<0.01$), reduced ADFI (linear; $P< 0.01$), and improved F/G (linear; $P<0.01$). Because of the linear response to increasing energy in our five basal diets, the F/G of pigs fed the diets containing DDGS could be compared to the F/G of the control diets. Thus, we estimated the ME of 1,586 and 1,419 kcal ME/lb for the Minnesota and Nebraska DDGS sources, respectively.

In Experiment 2, eight barrows (each initially 98.3 lb) were used in a Latin square design to determine the ME of the two DDGS sources used in Experiment 1. Diets were made up of 97% DDGS supplemented with crystalline amino acids, vitamins, and minerals to meet or exceed the pigs' nutrient requirements. There were no differences ($P>0.49$) for any growth traits; however, estimated digestible energy (DE) (1,756 vs. 1,691; $P<0.02$) and ME values (1,677 vs. 1,627; $P<0.05$) were greater than calculated in the growth trial.

The results of these two studies with the same batches of DDGS suggest possible variation in the energy value of DDGS based on how it is measured. In a nutrient balance study where pigs are individually fed a limited amount of feed, ME values were estimated to be higher than predicted from extrapolating our results from a growth trial. This leads us to speculate that in the growth trial, the decrease in ADFI and improvement in F/G observed from increasing DDGS may not have been a result of its increased energy content,

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but rather a palatability problem. Therefore, while it appears that the ME content of DDGS produced from relatively new processing plants appears to be comparable to that of corn, palatability problems may affect performance of pigs fed diets containing DDGS. Therefore, producers should exercise caution and evaluate potential variation and palatability before incorporating DDGS into their nutrition programs.

(Key Words: Distiller's Dried Grains with Solubles, Pigs, Energy)

Introduction

A recent study by the University of Minnesota has shown that distiller's dried grains with solubles (DDGS) have higher nutrient values than previously reported by the NRC (1998). A large number of new ethanol plants, which produce DDGS as a by-product, has increased the availability and attractiveness for use in swine diets. Traditionally, DDGS has been widely fed to ruminants because of the low lysine and high fiber content compared to other ingredients typically fed to pigs. New processing techniques and better quality control may lead to a better and more consistent nutrient profile of DDGS. Therefore, the objective of these trials was to determine a relative energy value for two DDGS sources: one from a relatively new ethanol plant, and the second from an older plant.

Procedures

In Experiment 1, a total of 360 pigs (each initially 38.5 lb) were blocked by weight and allotted randomly to one of nine dietary treatments. Treatments consisted of five corn-soybean meal-based diets with either added wheat bran or soy oil to provide five different energy densities (1,390 to 1,604 kcal ME/lb). The energy levels were selected because in a previous pilot study we had observed a linear response in feed efficiency within this energy range. These diets served to provide a reference to which we could then calculate an energy value for DDGS. The additional four treatments included either 15 or 30% DDGS from one of two different sources (Table 2). There were five pigs/pen and eight pens per treatment. The trial was conducted in the KSU Segregated Weaning Facility.

Experiment 2 was conducted, in an environmentally controlled metabolism at the KSU Swine Teaching and Research Facility. Eight non-littermate barrows (each initially 98.3 lb) were used in a nutrient balance study to determine the actual ME values of the two different DDGS used in Experiment 1. Pigs were fed diets containing 97% of one of the two DDGS sources. Crystalline amino acids, vitamins, and minerals were added to the diet to meet or exceed the pig's requirement (Table 3). The diets were formulated to have approximately 0.84% true digestible lysine.

Total tract digestibility was determined using ferric oxide as a marker. Ferric oxide was added at 1% of the diet in the ninth and fourteenth meals to mark the beginning and end of the collection period. This provided pigs 4 days to acclimate to their diet, followed by 3 days of feces and urine collection. Pigs were fed approximately 2.5% of BW on an as-fed basis. Daily feed allowances were equally divided between meals fed at 6 a.m. and 6 p.m. Water was provided at the rate of 2:1 water:feed (wt/wt) and then offered free choice after feeding. Feces and urine were collected twice daily. Feces were freeze-dried, ground, mixed, and a representative sub-sample was used for laboratory analysis. 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, mixed with each day's output, centrifuged to remove trace amounts of particulate matter, and analyzed.

Results and Discussion

For the overall 21-d trial, increasing energy density of the diet increased ADG (quad-

ratic, P<0.03) reduced ADFI (quadratic, P<0.06), and improved F/G (linear; P<0.01). There were no differences in ADG or F/G (P>0.16) among pigs fed either DDGS source; however, pigs fed Minnesota DDGS had lower ADFI (P<0.01) compared with those fed Nebraska DDGS.

Using the known energy content of the five basal treatments and the overall F/G, we calculated the ME of the DDGS diets by comparing F/G of pigs fed these diets to those of the five known energy densities (Figure 1). We could then estimate the energy content of the DDGS by subtracting the known energy values from the amounts of corn and soybean meal in the diet. Using this method, we calculated an ME value of 1,586 and 1,419 kcal for the Minnesota and Nebraska DDGS sources, respectively.

Using the same lots of DDGS from Experiment 1, we conducted a metabolism study to further determine the ME value for the two DDGS sources. In Experiment 2, there were no differences (P>0.49) for any growth traits. The Nebraska DDGS source had greater (P<0.01) gross energy (GE); however, the Minnesota DDGS had greater (P<0.05) DE (1,756 vs 1,691 kcal/lb) and ME (1,677 vs. 1,627 kcal/lb).

The results of our nutrient balance study show that the DDGS sources used have a higher ME value than estimated in the NRC (1998). However, these values are similar to those observed in trials conducted at the University of Minnesota. Furthermore, these results suggest that the ME from DDGS is 5% to 8% greater than that of corn.

In addition to determining DE and ME content of the two DDGS sources, we also calculated net energy. Net energy takes into account energy lost in feces, urine, and gas, as well as energy lost as heat during the process of digestion. By using equations developed to determine net energy from its chemical composition (starch, fat, ADF, and crude protein) we estimated the net energy value of our DDGS sources. Using this equation, the predicted NE value for these DDGS sources is 1,182 and 1,112 kcal/lb for Minnesota and Nebraska, respectively. Comparing the net energy of the two DDGS source to corn (NRC, 1998), we find the DDGS to contain only 90% to 96% of the Nebraska as corn. The discrepancy between ME and net energy values occurs because the ME system overestimates the energy from high-fiber and high crude protein ingredients and underestimates the energy from starch and oil-rich ingredients. The composition of corn (high starch and low fiber) and DDGS (high protein and high fiber) lead DDGS to have a higher ME relative to corn. This illustrates that evaluating feedstuffs on a net energy basis can be used to more precisely predict performance. Because a large portion of swine diets are corn based, replacing it with an energy source that is lower in net energy is likely to reduce performance.

A second possible explanation for the variation in the energy value of DDGS between our two studies may be related to feed intake. In the nutrient balance study, pigs were individually fed a limited amount of feed, ME values were estimated to be higher than predicted from extrapolating our results from a growth trial. This leads us to speculate that in the growth trial, the decrease in ADFI and improvement in F/G observed from increasing DDGS may not have been a result of its increased energy content, but rather the result of decreased palatability. If the DDGS were unpalatable enough to slightly reduce feed intake, this could also slightly improve F/G, which could be misinterpreted as a response to energy. Therefore, while it appears that the ME content of DDGS produced from relatively new processing plants appears to be comparable to that of corn, palatability problems may affect performance of pigs fed diets containing DDGS. Because of differences in the fiber content of DDGS, NE may be a more

reliable method of estimating energy content rather than ME. Therefore, producers should exercise caution and evaluate potential variation and palatability before incorporating DDGS into their nutrition programs.

Table 1. Composition of DDGS Sources[a]

Item	Minnesota	Nebraska
Dry matter	92.79	92.99
GE, kcal/lb	2,372	2,395
Crude protein, %	26.67	30.95
Crude fat, %	10.78	9.03
Crude fiber, %	5.61	7.62
Ash, %	6.16	3.91
Ca, %	0.84	0.60
P, %	0.83	0.49
K, %	0.88	0.50
Mg, %	0.30	0.16
NDF, %	26.03	32.61
ADF, %	6.85	9.97
Amino acids,%		
Lysine	0.78	1.08
Isoleucine	1.03	1.23
Leucine	3.28	3.97
Methionine	0.55	0.71
Met & Cys	1.08	1.42
Threonine	1.07	1.25
Tryptophan	0.19	0.21
Valine	1.40	1.66
Tyrosine	1.12	1.28
Phenylalanine	1.36	1.68
Histidine	0.75	0.98
Arginine	1.15	1.43

[a]Values are shown on an as-fed-basis.

Table 2. Composition of Diets for Experiment 1 (As-fed Basis)

	Dietary ME, kcal					DDGS	
Item	1,390	1,444	1,497	1551	1,604	15%	30%
Corn	41.42	51.42	61.45	59.10	56.73	46.84	32.27
Wheat bran	20.00	10.00	0.00	0.00	0.00	0.00	0.00
DDGS[a]	0.00	0.00	0.00	0.00	0.00	15.00	30.00
Soybean oil	0.00	0.00	0.00	2.35	4.70	0.00	0.00
Soybean meal, (46.5%)	34.69	34.70	34.70	34.69	34.69	34.70	34.68
Monocalcium P, (21% P)	1.23	1.38	1.51	1.51	1.53	1.12	0.73
Limestone	1.45	1.24	1.02	1.00	0.99	1.13	1.23
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15
L-Threonine	0.12	0.13	0.14	0.15	0.15	0.11	0.07
L-Lysine HCl	0.23	0.26	0.29	0.30	0.31	0.26	0.23
DL-Methionine	0.12	0.13	0.15	0.16	0.16	0.10	0.06
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis							
Lysine, %	1.46	1.45	1.44	1.44	1.44	1.47	1.50
Isoleucine:lysine ratio, %	0.66	0.65	0.64	0.64	0.63	0.71	0.77
Leucine:lysine ratio, %	1.28	1.29	1.31	1.29	1.28	1.44	1.58
Methionine:lysine ratio, %	0.32	0.33	0.34	0.34	0.34	0.33	0.33
Met & Cys:lysine ratio, %	0.60	0.59	0.60	0.60	0.59	0.62	0.65
Threonine:lysine ratio, %	0.67	0.67	0.66	0.67	0.67	0.68	0.68
Tryptophan:lysine ratio, %	0.20	0.19	0.18	0.18	0.18	0.20	0.21
Valine:lysine ratio, %	0.75	0.73	0.71	0.71	0.70	0.79	0.87
ME, kcal/lb	1,390	1,444	1,497	1,551	1,604	1,483	1,551
Protein, %	22.79	22.08	21.36	21.15	20.95	24.27	27.18
Calcium, %	0.94	0.87	0.80	0.80	0.79	0.80	0.79
Phosphorus, %	0.85	0.79	0.73	0.72	0.72	0.72	0.71
Available P, %	0.40	0.40	0.40	0.40	0.40	0.40	0.40

[a]NRC (1998) values were used for ME values and amino acid digestibility coefficients.

Table 3. Composition of Diets for Experiment 2 (As-fed Basis)

	Source	
Ingredient, %	Minnesota	Nebraska
Distiller's dried grains with solubles	96.92	96.92
Limestone	1.65	1.65
Salt	0.35	0.35
Vitamin premix	0.25	0.25
Trace mineral premix	0.15	0.15
L-Threonine	0.01	---
L-Lysine HCl	0.63	0.41
Tryptophan	0.06	0.04
Sand	---	0.24
Total	100.00	100.00
Calculated analysis		
Lysine, %	1.15	1.15
Isoleucine:lysine ratio, %	0.87	1.04
Leucine:lysine ratio, %	2.76	3.35
Methionine:lysine ratio, %	0.46	0.60
Met & Cys:lysine ratio, %	0.91	1.20
Threonine:lysine ratio, %	0.91	1.05
Tryptophan:lysine ratio, %	0.21	0.21
Valine:lysine ratio, %	1.18	1.40
ME, kcal/lb[a]	1,638	1,586
Protein, %	26.85	26.85
Ca, %	0.82	0.82
P, %	0.75	0.75
Available P, %	0.57	0.57
True digestible amino acids		
Lysine	0.94	0.94
Isoleucine:lysine ratio, %	78	93
Leucine:lysine ratio, %	268	324
Methionine:lysine ratio, %	43	55
Met & Cys:lysine ratio, %	67	88
Threonine:lysine ratio, %	72	84
Tryptophan:lysine ratio, %	20	20
Valine:lysine ratio, %	97	115

[a]Estimated values.

Table 4. Effects of 15 & 30% DDGS on Growth in Phase III Nursery Diets. Experiment 1[a]

										Probability P<			
	Dietary ME, kcal					Nebraska DDGS, %		Minnesota DDGS, %		Model[b]			
Item	1,390	1,444	1,497	1,551	1,604	15	30	15	30	Liner	Quad	Source	SE
D 0 to 22													
ADG, lb	1.48	1.60	1.59	1.59	1.61	1.60	1.57	1.59	1.52	0.01	0.03	0.19	0.038
ADFI, lb	2.49	2.49	2.53	2.42	2.37	2.52	2.50	2.45	2.38	0.01	0.06	0.01	0.072
F/G	1.67	1.56	1.58	1.53	1.48	1.58	1.59	1.55	1.56	0.01	0.48	0.16	0.022

[a]Values represent the means of 360 pigs (each initially 38.5 lb) with 5 pigs per pen and 8 replicate pens per treatment.
[b]Model includes all treatments except diets with DDGS.

Table 5. Growth Performance and Calculated Energy Values of Dried Distiller Grains & Solubles Experiment 2[a]

Item	Minnesota	Nebraska	SEM	Probability P<
Growth				
ADG, lb	0.91	0.90	0.160	0.90
ADFI, lb	2.05	2.02	0.119	0.49
F/G	2.29	2.52	0.352	0.50
Energy Values, kcal/lb				
GE	2,201	2,227	4.8	0.01
DE	1,756	1,691	43.0	0.02
ME	1,677	1,627	42.0	0.05
NE[b]	1,182	1,112	-	-

[a]Represents the means of eight pigs (each initially 98.3 lb) used in a Latin square design, metabolism study was conducted as four-day adaptation followed by a three-day collection.
[b]Calculated: NE = (ME × 0.726) + (13.3 × % Fat) + (3.9 × % Starch) – (6.7 × % Crude Protein) – (8.7 × % ADF) using Noblet et al. (1994).

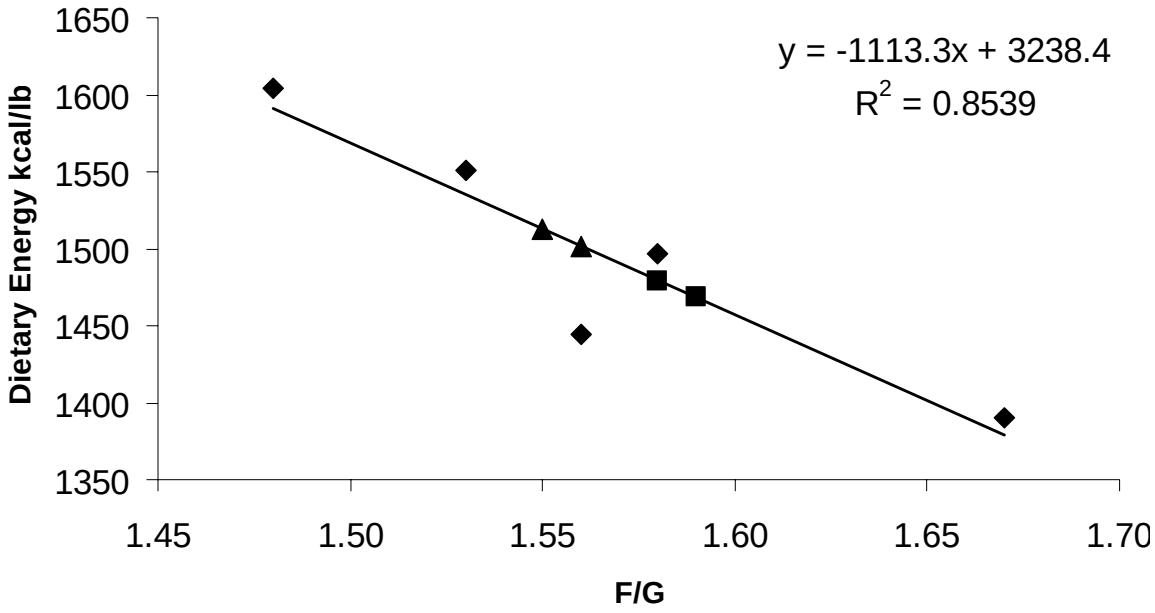

Figure 1. Relationship between Dietary Energy Density and Mean Feed Efficiency.

♦ Represents base diets with known dietary ME.

■ Represents calculated dietary ME for pigs fed Nebraska source DDGS. This value was used to calculated Nebraska DDGS ME value.

▲ Represents calculated dietary ME for pigs feed Minnesota source DDGS. This value was used to back calculated Minnesota DDGS ME value.

THE EFFECTS OF REDUCING DIETARY CRUDE PROTEIN AND/OR ADDING CHICORY ON COMPOSITION AND ODOR OF STORED SWINE MANURE[1]

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Summary

A feeding study was conducted to compare nutrient excretion and odor analysis of pigs fed either a conventional corn-soybean meal diet, or a diet formulated to minimize nutrient excretion and odors through use of crystalline amino acids, phytase, and non-sulfur containing trace minerals. These diets (0.85% true digestible lysine), were fed to pigs (each initially 130 lb) with or without chicory, a feed ingredient speculated to reduce odors in swine waste.

Dietary treatments were arranged in a 2 x 2 factorial, with main effects of diet nutrient excretion potential (low or high) and chicory (0 or 10%). Twelve nonlittermate barrows were fed each of the four diets over four, 10-d periods in a replicated 4 × 4 Latin square design. Each pig was housed in a stainless steel metabolism cage (5 × 2 ft) designed to allow separate collection of urine and feces. Feces and urine were collected between the seventh and eleventh meals in order to measure nitrogen (N), sulfur (S), and phosphorus (P) intake, excretion, and retention. Feces and urine also were collected the last two days of each period and mixed into a 7.5% DM slurry for odor analysis at the University of Minnesota Olfactometry Laboratory. The 7.5% DM slurries were measured for pH, total solids (TS), total volatile solids (TVS), ammonia, total Kjeldahl nitrogen (TKN), hydrogen disulfide (H2S), percentage sulfur (sum of sulfur in air and slurry samples), and Ca, K, Mg, Na, and P. Air samples collected from the slurries were measured for H2S, intensity, and offensiveness.

Pigs fed diets formulated to reduce nutrient excretion and odor had a 20% and 34% reduction ($P<0.001$) in total N and P excretion, respectively, and a 33% reduction in urinary S excretion. The addition of chicory to the diet further reduced ($P<0.002$) N and P excretion by 10% and 14%, respectively. Pigs fed the diets formulated to reduce nutrient excretion and odor had lower ($P<0.001$) total pH, ammonia, sulfur dry weight percentage, and TKN in the slurry samples. However, H2S emission, odor intensity and offensiveness were not affected ($P<0.19$). These results indicate that formulating a diet to meet the needs of a pig, yet lower nutrient excretion by use of synthetic amino acids, phytase, non-sulfur-containing trace mineral premixes and the addition of chicory will reduce nutrient excretion in swine manure, but do not appear to affect the intensity or offensiveness of odors.

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[2]Food Animal Health and Management Center.

(Key Words: Pigs, Chicory, Odor, Nutrient Excretion, Phytase)

Introduction

Concern about odor emissions and nutrients from livestock manure overloading the soil and entering waterways has become a major issue for the swine industry in the past few years. Several compounds are associated with the odor of swine manure: ammonia, amines, sulfur-containing compounds, volatile fatty acids, indole, skatole, phenols, alcohols, and carbonyls. Several nutrients – such as N, P, and S – in feed ingredients are not completely digested by pigs. These excess nutrients are then excreted as waste and deposited in lagoons or spread on nearby fields.

Several compounds associated with the odor and nutrient levels in swine manure have been altered through diet or microbial manipulation. It was shown that by adding 3% or 6% Jerusalem artichoke to the diet, swine manure had a sweeter, less sharp and pungent odor, and less of a skatole smell than pigs eating the control diet. The tuber of the Jerusalem artichoke is rich in the carbohydrate inulin, a fructose polymer. Chicory (Cichorium intybus) is also rich in inulin. These fructose polymers (fructooligosaccharides) have been shown to alter volatile fatty acid (VFA) patterns by increasing the population of bifidobacteria in the hindgut and thus reducing odor in feces. Research has also shown that adding 5% chicory to the diet significantly reduces skatole in manure of pigs fed a corn-soy diet. However, in this same study, added inulin had no effect on nitrogen-related odor.

Many of the compounds found to cause odor are related to the degradation of excess amino acids commonly found in diets. Research has shown that by reducing the dietary crude protein content by 4% and formulating the diet to meet the requirements for the first four limiting amino acids with crystalline amino acids, aerial ammonia concentrations could be reduced by 29%. The impact of crystalline amino acid supplementation with low-CP diets to reduce N excretion has been shown to range from 3.2 to 6.2%, depending on the weight of the pig, level of dietary CP reduction, and initial CP level in the control diet.

Our objective was to determine the effect of chicory supplementation on nutrient excretion and odor characteristics in stored manure. In addition, we evaluated several other technologies that are known to lower the odor and nutrient level of swine waste including: 1) use of low protein, amino acid-fortified diets; 2) use of nonsulfur-containing trace mineral premixes; and 3) use of phytase to lower the diets phosphorus level. The use of a combination of these technologies provides a model to test the effectiveness of chicory addition on nutrient excretion and emission of ammonia, sulfur, and other odor-causing compounds.

Procedures

Twelve nonlittermate barrows, each weighing approximately 130 lb, were used in a 4 × 4 replicated Latin square design. The Latin square consisted of four consecutive periods, with each period lasting 10 days. At the beginning of each period, pigs were weighed and randomly assigned to a dietary treatment, treatments then changed with every 10-d period so that each pig was fed all four of the experimental diets. All diets (Table 1) were formulated to provide 0.85% true digestible lysine and were fed in meal form. A typical, 18% CP corn-soybean meal diet was formulated with no crystalline L-lysine HCl or phytase (0.51% available P). This diet also used a trace mineral premix with the sulfur-containing form of the various trace minerals. We expected our formulation method of this diet to have high nutrient excretion in waste and potential for odor production. The other diet was formulated to reduce nutrient excretion and odor through the use of crystalline amino acids, added phytase, and a replace-

ment of the sulfur-containing trace minerals with other forms. The typical (high nutrient excretion), or low protein (low nutrient excretion) diets were fed with none or 10% chicory added. Pigs were fed at 3% their body weight, divided equally among two feedings, with ad libitum access to water. We designed our experimental treatments such that by having high and low nutrient excretion and odor dietary treatments, we should be able to detect differences in nutrient excretion and odor. We could then evaluate the effectiveness of added chicory compared with the high or low nutrient excretion diets.

Pigs were housed in individual stainless steel metabolism crates design for separate collection of feces and urine. Each pig was allowed three days to adapt to the dietary treatments followed by a three-day collection period of feces and urine. Feces and acidified urine were collected twice daily and frozen until analysis. Then, on the final two days of each period, all feces and urine (non–acidified) were collected for the simulated anaerobic pit system. Simulated anaerobic pit systems are designed to mimic an anaerobic manure system, in which the manure can be analyzed for nutrient content and odor production. Feces and urine were collected twice daily and refrigerated until the end of the two-day collection period. After all feces and urine were collected, feces from pigs fed the same diets were blended and DM content was determined for the blended feces. Urine from pigs fed the same diets also was blended. The feces and urine were then blended together to form a 7.5% DM slurry for each treatment. From this slurry, 19 sub-samples were collected with the samples being one 2-L sample, and eighteen 50-ml aliquots. The samples were stored in separate plastic containers and labeled, then frozen until the completion of the four periods and shipped to the University of Minnesota Olfactometry Laboratory for odor and nutrient content analyses.

At the University of Minnesota, each 2-L sample was thawed and placed in a simulated anaerobic pit. The simulated anaerobic pits were then stored in an environmentally-controlled chamber with a constant temperature. A 50 ml aliquot (from the same original sample) was thawed and added to each simulated pit two times a week (Tuesday and Thursday) to feed the bacterial population. Nutrient and odor analysis was conducted on days 28 and 56.

On the day of odor and nutrient analysis, each simulated pit was agitated, and a 100 ml sample was pipetted from the simulated pit. Air samples were taken by placing the 100 ml samples into glass flasks, and covering the flask with a rubber stopper with an inlet and outlet. Charcoal-filtered nitrogen gas was moved over the headspace of the flask at a rate 1.5L/min for 50 minutes in order to purge existing gases. After 50 minutes, a 10-L Tedlar bag was attached to the outlet and filled using a vacuum box.

The air samples were then analyzed for odor units using dynamic olfactometry and total reduced sulfur (TRS) concentration using a Jerome® meter. Each 100 ml sample was then analyzed for total solids (TS), pH, total volatile solids (TSV), total nitrogen (tN), ammonium nitrogen (NH3 – N), total sulfide, and total minerals.

Results and Discussion

The volume of nutrients excreted through urine and feces is an important environmental concern. If the land base for manure application and storage capacity is limited, decreasing manure and nutrient outputs becomes a crucial issue to a swine operation. In our study, there were no differences ($P>0.19$) in fecal wet weight or fecal dry weight between pigs fed any of the four dietary treatments (Table 2). However there was a nutrient excretion level by chicory interaction ($P<0.03$) for fecal dry matter percentage. This difference in percent-

age fecal DM appears to be partially due to the slightly higher (3% increase; P<0.001) DM intake for pigs fed diets formulated to reduce odor and nutrient excretion. Including chicory in the diet also appears to increase the moisture content of the feces, as evidenced by lower fecal dry matter for pigs fed diets including chicory. Pigs fed the diets formulated to reduce odor and nutrient excretion excreted 7% less (P<0.03) urine than pigs fed the conventional corn-soybean meal diets, while the addition of chicory further reduced (P<0.001) urine output by 13%. The reduction in urine output could have been affected by the amount of water intake. We did not measure water intake in our study, but all pigs were offered water ad libitum. It appears that including chicory in the diet alters the route of excretion for water to decrease excretion in the urine and increase excretion in the feces. Pigs fed low nutrient excretion diets had higher (P<0.01) ADFI than pigs fed the high nutrient excretion diets. The difference in intake is a result of feeding the pigs 3% of their body weight instead of feeding a constant level during each stage. Neither diet formulation method nor added chicory affected DE, ME, or DE as a percentage of gross energy of the diet.

There was a nutrient excretion level by chicory interaction (P<0.001) for N intake. As expected, pigs fed the diets formulated to reduce nutrient excretion and odor had decreased N intake compared to pigs fed the high protein diets. The reduction of N intake between the two formulation methods was due to a 22% reduction in CP by the use synthetic amino acids. The interaction occurred because the addition of chicory to the low nutrient excretion diet decreased N intake 16% whereas there was no change in N intake when adding chicory to the conventional corn-soybean diet. The reason for this anamoly is two-fold. First, pigs fed the low nutrient excretion diet without chicory had higher total feed intake, as discussed earlier. Second, the low nutrient excretion diet without chicory had a higher analyzed protein content than expected, leading to higher calculated N intake.

Total N excretion was reduced by 20% (P<0.001) when pigs were fed diets formulated to reduce nutrient excretion and odor. Added chicory further reduced (P<0.03) total N excretion by 10% and 14% for pigs fed the diets formulated for low nutrient excretion and the conventional corn-soybean meal diets, respectively. Similar to total N excretion, urinary N excretion was reduced 36% (P<0.001) for pigs fed diets formulated for lower nutrient excretion and odor. The addition of chicory reduced (P<0.01) urinary N level by 17% and 13% in pigs fed the diets formulated for lower nutrient excretion and the conventional corn-soybean meal diets, respectively. Fecal N excretion tended to be numerically higher (P>0.09) with the addition of chicory. Other research has shown that when a fermentable carbohydrate (such as chicory) is added, increase in fecal N excretion and a decrease in urinary nitrogen are often observed. A nutrient excretion level by chicory interaction (P<0.008) was observed for nitrogen retention (g/day). Adding chicory reduced N retention when added to the diets formulated to decrease nutrient excretion, but increased N retention in pigs fed the conventional corn-soybean meal diets. As the diets were formulated closer to the pigs' amino acid requirements with the use of synthetic amino acids, there was a 15% improvement (P<0.001) in N retention (%) for pigs fed the diets formulated for low nutrient excretion and odor.

Phosphorus (P) intake was reduced 26% (P<0.001) for pigs fed the diets formulated for low nutrient excretion and odor compared to the conventional corn-soybean meal diets. The addition of chicory to the diet decreased (P<0.001) P intake an additional 13% and 10% for pigs fed the diets formulated for lower nutrient excretion and those fed the conventional corn-soybean meal diets, respectively. A nutrient excretion level by chicory interaction (P<0.002) was observed for total P

excreted and fecal P excreted. This appeared to be a result of a low level of P excreted in the diets formulated for lower nutrient excretion and odor. A further reduction was seen when chicory was added to this diet. Urinary P excretion was not affected (P<0.08) by dietary nutrient excretion level or the addition of chicory. Phosphorus retention (g/d and %) was increased when pigs were fed diets formulated for low nutrient excretion and odor but increased in those fed the conventional corn-soybean meal diets (nutrient excretion level by chicory interaction, P<0.002).

Sulfur (S) intake decreased with the addition of chicory to diets formulated to lower nutrient excretion and odor, but increased in the conventional corn-soybean meal diets (nutrient excretion level by chicory interaction, P<0.001). However, pigs fed the diets formulated to reduce nutrient excretion and odor had a lower S intake (P<0.001) than pigs fed the conventional corn-soybean meal diets. The diets formulated to reduce nutrient excretion and odors were created with a nonsulfur-containing trace mineral premix and DL-methionine to minimize S intake. When the diets were analyzed for S, diets formulated to reduce nutrient excretion and odor with chicory had a lower level of S than the conventional corn-soybean meal diet. Urinary sulfur excretion was 33% lower (P<0.001) for pigs fed diets formulated to reduce nutrient excretion and odor. There was no effect (P<0.18) of nutrient excretion level, chicory level, or chicory by nutrient excretion interaction for total S excreted, or fecal S excreted. A nutrient excretion level by chicory interaction (P<0.001) for S retention was expressed on a g/d or percentage of S intake basis. The addition of chicory reduced S retention for pigs fed diets formulated to lower nutrient excretion and odor, and increased S retention for pigs fed conventional corn-soybean meal diets.

The odor and other response criteria for the 7.5% DM slurry from individual dietary treatments were analyzed on d 28 and 56 of storage (Tables 3 and 4). In general, the magnitude of results changed over time (Table 4), but few dietary treatments changed by day of storage interactions.

Slurry pH was decreased (P<0.01) for pigs fed diets formulated to lower nutrient excretion compared with those fed the conventional corn-soybean meal diets. The differences in pH observed may be because of the lower urinary N excretion. A reduction (P < 0.04) of total solids occurred when chicory was added to diets, which may be due to the lower percentage DM excreted by pigs fed diets containing chicory.

Manure slurry ammonium nitrogen (NH3 – N) and TKN were reduced (P<0.01) 18% and 15%, respectively for pigs fed diets formulated to lower nutrient excretion and odor. The difference in NH3 – N and TKN levels between the two methods of formulation was due to lower nitrogen input and better retention of nitrogen with the use of synthetic amino acids in diets formulated for lower nutrient excretion and odor. The addition of chicory did not have an effect (P>0.84) on the NH3 – N or TKN in the slurry.

There were no differences in (P>0.19) H2S in the air samples measured by the Jerome meter or measured in the slurry sample. The percentage S dry weight was reduced (P<0.001) by 21% when pigs were fed with the diets formulated to lower nutrient excretion, due to the use of non–S containing trace mineral premix and DL-methionine. However, added chicory tended to increase (P<0.08) percentage S in the slurry on a dry weight basis.

There were several reductions for Ca, K, Mg, Na, and P when diets were closely formulated to meet the needs of the pig. Ca, Na, and P were reduced (P<0.001) due to the use of lower crude protein diets formulated with phytase. Calcium, P, and Mg were further re-

duced (P<0.001) with the use of chicory. The reduction in the mineral content of the slurry, because of diet formulation and the use of chicory, will help to reduce the buildup of minerals in the soil and surrounding waters due to land application.

There were no differences (P>0.22) for odor intensity or odor offensiveness among dietary treatments. This implies that formulation technique, including crystalline amino acids, phytase, nonsulfur-containing trace mineral premixes, and the addition of chicory had no effect on reducing the relative offensiveness of swine manure odors.

From d 28 to d 56, pH of the simulated anaerobic pits was reduced (P<0.01) by 3%. The addition of the 50 ml aliquots each week to the simulated pits simulated the addition each day in a hog facility. These additions increase both the number of bacteria and the amount of nutrients (proteins) in the slurry. As the bacteria population increase the amount of proteins that are broken down also increase, which cause a decrease in slurry pH.

The addition of the 50 ml aliquots to the simulated pits twice a week was intended to maintain a 7.5% DM slurry. However from d 28 to d 56, there was a reduction (P<0.01) of percentage total solids. This reduction of solids was due to the bacterial population breakdown of nutrients.

From d 28 to d 56, manure slurry NH3 – N and TKN increased (P<0.001) 23% and 18%, respectively. The difference in NH3 – N and TKN levels between d 28 and d 56 was due to the increase in slurry, which added nutrient high in nitrogen.

When the air samples collected off of the slurry were tested by the olfactometry panelist, odor intensity was scored lower (P<0.001) for d 56. This reduction was not seen for either the formulation methods or interaction with chicory. Because of the lack of interaction seen between the formulation methods, we concluded that this reduction is not due to treatment but instead due to scoring of the panelist or reduction in other odor compounds over time.

Implications

Using formulation techniques, such as reducing the CP in a diet with the use of synthetic amino acids, using nonsulfur-containing trace mineral premixes, adding phytase to the diet, and the inclusion of chicory, may have added benefits to the environment. The diets formulated to lower nutrient excretion and odor reduced total and urinary nitrogen excretion, while chicory helped reduce fecal nitrogen by 5%. Phosphorus was reduced by 34% with the addition of phytase in the diet, while sulfur was reduced 33% due to the use of nonsulfur-containing trace mineral and the addition of DL–methionine. The addition of chicory at 10% of the diet was also beneficial in reducing the amount of P and N excreted in this study. Pigs fed the diets formulated to reduce nutrient excretion and odor had lower total pH, ammonia, sulfur dry weight percentage, and TKN in the slurry samples. However, H2S emission, odor intensity and offensiveness were not affected. The diet formulation alteration and addition of chicory did not have a negative affect on growth performance while reducing the excretion levels of the pig. These diet alterations may provide a method to further reduce the level of odor and nutrients leaving the swine farm.

Table 1. Diet Composition (As-fed Basis)

Nutrient excretion level:	Low[c]		High[d]	
Ingredient, % Chicory, %:	0	10	0	10
Corn	81.15	70.90	71.65	61.45
Soybean meal, 46.5% CP	16.55	16.85	25.90	26.25
Chicory	--	10.00	--	10.00
Monocalcium phosphate, 21% P	0.23	0.23	0.65	0.65
Limestone	0.97	0.88	1.17	1.06
Salt	0.35	0.35	0.35	0.35
Vitamin premix[a]	0.13	0.13	0.13	0.13
Trace mineral premix[b]	0.13	0.13	0.13	0.13
L-Tryptophan	0.01	0.01	--	--
L-Threonine	0.08	0.09	--	--
L-Lysine HCl	0.30	0.30	--	--
DL-Methionine	0.05	0.07	--	--
Phytase[e]	0.08	0.08	--	--
Total	100.00	100.00	100.00	100.00
Calculated analysis.				
Total Lysine, %	0.95	0.95	0.97	0.97
True digestible lysine, %	0.85	0.85	0.85	0.85
True digestible amino acid ratios, %				
Isoleucine:lysine	61	60	79	78
Leucine:lysine	150	142	176	168
Methionine:lysine	32	34	31	30
Met & Cys:lysine	60	60	65	62
Threonine:lysine	63	63	69	68
Tryptophan:lysine	17	17	22	22
Valine:lysine	71	70	89	88
Metabolizable energy, Mcal/kg	3.35	3.35	3.33	3.32
Protein, %	14.6	14.3	18.1	17.9
Ca, %	0.50	0.50	0.67	0.66
P, %	0.39	0.38	0.52	0.51
Available P equiv, %	0.21	0.21	0.21	0.21
Chemical analysis				
Crude protein, %	16.47	14.90	18.53	18.75
P, %	0.39	0.35	0.55	0.50
S, %	0.16	0.14	0.17	0.19
Gross energy, Mcal/kg	3.99	4.01	4.03	3.99

[a]Provided the following per kilogram of complete diet: vitamin A, 11,023 IU; vitamin D3, 1,653 IU; vitamin E, 44 IU; menadione (menadione bisulfate complex), 4.4 mg; vitamin B12, 0.04 mg; riboflavin, 9.9 mg; pantothenic acid, 33 mg; and niacin, 55 mg.

[b]Provided the following per kilogram of complete diet: Mn, 40 mg; Fe, 165 mg, Zn, 165 mg, Cu, 17 mg, I, 0.3 mg; and Se, 0.3 mg.

[c]Trace mineral premix formulated with: zinc oxide, ferric chloride, manganese oxide, cupric chloride, and calcium iodate and sodium selenite.

[d]Trace mineral premix formulated with: zinc sulfate, ferrous sulfate, manganese sulfate, cupric sulfate, calcium iodate, and sodium selenite.

[e]Provided 300 FTU/kg of feed (Natuphos® 600).

Table 2. The Effects of Reducing Dietary Crude Protein and Adding Chicory on Nutrient Availability[a]

	Nutrient level:	Low		High			P< value		
Items	Chicory, %:	0	10	0	10	SED	Nutrient level	Chicory	Interaction
Fecal									
Wet weight excreted, g		1,390	1,425	1,344	1,432	83	0.74	0.30	0.66
DM, %		33	29	31	29	0.5	0.02	0.001	0.03
Dry weight excreted, g		458	414	416	417	23	0.24	0.19	0.19
Urine excreted, ml		7,254	5,946	7,471	6,838	347	0.03	0.001	0.18
Feed									
ADFI, g/d		1823	1,783	1,746	1,738	18	0.001	0.08	0.23
Digestible energy, %		86	87	87	88	1	0.13	0.16	0.40
Digestible energy, Mcal/kg		3.44	3.50	3.52	3.49	---	---	---	---
Metabolizable energy, Mcal/kg		3.32	3.39	3.37	3.35	---	---	---	---
Nitrogen									
Intake, g		111.3	99.2	123.9	126.2	1.3	0.001	0.001	0.001
Total excreted, g		49.0	43.5	68.2	62.6	3.5	0.001	0.03	0.99
Urinary excreted, g		36.0	30.1	54.5	48.0	3.4	0.001	0.01	0.92
Fecal excreted, g		13.0	13.4	13.7	14.6	0.8	0.09	0.23	0.68
Retention, g		62.3	55.7	55.6	63.6	3.6	0.82	0.80	0.008
Retention, %		56.3	56.1	45.1	50.8	3.3	0.001	0.25	0.21
Phosphorus									
Intake, g		14.8	13.0	20.0	17.9	0.2	0.001	0.001	0.25
Total excreted, g		8.8	6.1	11.2	11.1	0.6	0.001	0.002	0.005
Urinary excreted, mg		1.6	2.8	3.1	2.5	0.7	0.20	0.53	0.08
Fecal excreted, g		8.8	6.0	11.2	11.1	0.6	0.001	0.002	0.005
Retention, g		6.0	7.0	8.8	6.8	0.6	0.004	0.26	0.002
Retention, %		40.3	53.4	43.6	38.5	3.7	0.03	0.13	0.001
Sulfur									
Intake, g		6.0	5.1	6.2	6.8	0.1	0.001	0.03	0.001
Total excreted, g		2.2	2.1	2.1	2.2	0.1	0.87	0.61	0.19
Urinary excreted, mg		59.7	58.3	88.1	86.2	9.2	0.001	0.80	0.98
Fecal excreted, g		2.1	2.0	2.0	2.1	0.1	0.86	0.59	0.18
Retention, g		3.8	3.0	4.1	4.6	0.1	0.001	0.05	0.001
Retention, %		64.0	59.0	66.4	67.5	1.9	0.001	0.17	0.03

[a]Values are means of 12 barrows (59 to 207 kg) over four periods with 3 pigs per treatment per period.

Table 3. The Effects of Reducing Dietary Crude Protein and Adding Chicory on Odor Quality[a]

	Nutrient level:	Low		High			P< value			
Item	Chicory, %:	0	10	0	10	SED	Day	Nutrient level	Chicory	Interaction
pH		8.4	8.2	8.6	8.6	0.11	0.01	0.01	0.17	0.34
Total solid, %		9.4	8.8	9.3	8.8	0.38	0.01	0.78	0.04	0.87
Total volatile solid, %		6.4	6.4	6.5	6.0	0.30	0.08	0.54	0.37	0.26
NH3-N, mg/L		4,495	4,763	5,757	5,527	490	0.001	0.01	0.96	0.48
Total Kjeldahl nitrogen, mg/L		6,014	6,722	7,876	7,046	414	0.001	0.001	0.84	0.02
H2S, ppm		1.0	1.7	0.7	1.0	2.01	0.36	0.19	0.24	0.64
H2S Air, ppm		0.6	0.8	1.2	1.0	0.50	0.44	0.34	0.97	0.59
Sulfur dry weight, %		68.5	78.2	91.5	95.1	5.0	0.06	0.001	0.08	0.41
Ca, ppm		70,453	30,891	44,115	43,577	4,366	0.01	0.04	0.001	0.001
K, ppm		18,352	21,649	22,932	22,517	2,659	0.49	0.16	0.45	0.33
Mg, ppm		6,224	5769	7,697	5,904	694	0.29	0.12	0.03	0.19
Na, ppm		5,190	4,565	4,024	3,913	520	0.54	0.02	0.33	0.49
P, ppm		10,273	8,637	15,179	12,245	1,171	0.57	0.001	0.01	0.44
Intensity		5.0	4.9	5.2	5.0	0.21	0.001	0.22	0.36	0.80
Offensives		-2.7	-2.9	-3.0	-2.8	0.33	0.96	0.67	0.96	0.52

[a]Values are means of 16 samples with four samples per treatment over two sampling periods.

Table 4. The Effects of Storage Time on Manure Slurry and Odor[a]

	Day			P< value
Items	28	56	SED	Day
pH	8.57	8.35	0.11	0.01
Total solid, %	9.50	8.65	0.38	0.01
Total volatile solid, %	6.51	6.13	0.30	0.08
NH3-N, mg/L	4,483	5,788	490.33	0.001
Total Kjeldahl nitrogen, mg/L	6,243	7,586	413.95	0.001
H2S, ppm	1.30	0.90	2.01	0.36
H2S Air, ppm	1.04	0.76	0.50	0.44
Sulfur dry weight, %	79.7	87.0	5.0	0.06
Ca, ppm	51,698	42,820	4366	0.01
K, ppm	22,021	20,704	2659	0.49
Mg, ppm	6,663	6,134	694	0.29
Na, ppm	4,538	4,308	520	0.54
P, ppm	11,823	11,344	1171	0.57
Intensity	6.0	4.0	0.21	0.001
Offensives	-2.8	-2.8	0.33	0.96

[a]Values are means of 16 samples with four samples per treatment over two sampling periods.

Swine Day 2003

PARTICLE SIZE, MILL TYPE, AND ADDED FAT INFLUENCE FLOW ABILITY OF GROUND CORN

C.N. Groesbeck, R.D. Goodband, M.D. Tokach, J.L. Nelssen, S.S. Dritz[1], K.R. Lawrence, and C.W. Hastad

Summary

We conducted three experiments to determine effect of particle size, mill type, and added fat on flow characteristics of ground corn. In Experiment 1, corn was ground with either a hammer mill or a roller mill to produce six samples with different particle sizes. The particle size for the corn ground with a roller mill ranged from 1,235 to 502 microns with standard deviation ranging from 1.83 to 2.03. Particle size for corn ground with a hammer mill ranged from 980 to 390 microns with standard deviation ranging from 2.56 to 2.12. All samples were dried 12 hours to equalize moisture content. Soy oil was then added at 0, 2, 4, 6, and 8% to each sample.

Flow ability was determined by measuring angle of repose (the maximum angle measured in degrees at which a pile of grain retains its slope). A large angle of repose represents a steeper slope and poorer flow ability. There was a three-way interaction ($P<0.05$) between particle size, added fat, and mill type. Roller mill ground corn had better flow ability than hammer mill ground corn, and decreasing particle size while increasing added fat, increased the angle of repose. However as particle size decreased and added fat increased, the differences between hammer mill and roller mill ground grain decreased. Corn ground with a hammer mill without added fat had a similar angle of repose to corn ground with a roller mill that had 6% added fat.

For both Experiments 2 and 3, batches of roller mill and hammer mill ground corn were sifted with a Ro-Tap tester through a stack of 13 screens. The material on top of each screen was then collected. Samples were dried 12 hours to equalize moisture content. Soy oil was added at 0, 4, and 8% to each sample. In Experiment 2, five roller mill samples were selected from different individual screens with mean particle size ranging from 1,415 to 343 microns and 5 hammer mill samples ranging from 1,382 to 333 microns. All samples were selected from the ground corn remaining on top of the individual screens. By selecting samples this way, both roller mill and hammer mill samples had similar particle size standard deviation (PSSD), ranging from 1.1 to 1.3. There was an interaction ($P<0.05$) between particle size, added fat, and mill type. Increasing fat and decreasing particle size increased the angle of repose. However, in fine ground hammer mill ground corn, the differences between amounts of added fat became less as particle size decreased, whereas in roller mill ground samples the differences were maintained. In roller mill ground grain samples, decreasing particle size had less negative impact on flow ability than in hammer mill ground grain.

[1]Food Animal Health and Management Center.

In Experiment 3, we used 4 roller mill and 4 hammer mill samples that were constructed from the previously collected grain. All samples were constructed to have a similar mean particle size (641 to 679 microns) with increasing PSSD (1.62 to 2.27). There was no interaction (P>0.10) between PSSD, added fat, and mill type. Increasing fat (P<0.04) and PSSD (P<0.001) decreased flow ability. These data suggest that the greater flow ability of roller mill ground corn compared to hammer mill ground corn appears to be a result of less particle size variation. However, with fine particle sizes other factors, such as particle shape, may also contribute to flow ability.

(Key Words: Particle Size, Added Fat, Hammer Mill, Roller Mill)

Introduction

Decreasing particle size between 600 and 700 microns and adding fat to diets can improve pig performance and profitability. Limits to reducing grain particle size and amount of added fat are frequently based on the ability of the feed to flow through feed delivery systems and feeders. Type of grinding may also affect feed flow ability. Grain ground with a roller mill typically has a more uniform particle size and less particle variation than that ground with a hammer mill. Therefore we conducted three experiments to evaluate the effects of particle size, added fat, mill type, and particle size standard deviation on flow characteristics of ground corn.

Procedures

All three experiments were conducted using corn ground either by a full circle, tear drop hammer mill or three high roll, roller mill at the Kansas State University Grain Science Feed Mill. The corn contained 10.3% CP and 3.2% fat on an as-fed basis. Corn was dried 12 hours to equalize moisture content, resulting in a dry matter of 96%. Particle size and standard deviation were determined with a Ro-Tap tester with a stack of 13 screens, as outlined in the American Society of Agricultural Engineers (publication S319). Angle of repose is defined as the maximum angle measured in degrees at which a pile of grain retains its slope. An angle of repose tester was constructed from 4 pieces of poly vinyl chloride (PVC). The tester is 3" in diameter and 36" tall and attached to a 3" PVC floor mounting. A 3" diameter plate was mounted to the top of the machine to allow two 3" PVC couplers that were planed to slide up and down the long axis of the tester. To conduct the angle of repose test, a 500g sample was placed inside the couplers at a specified height at the top. The base of the angle of repose tester was held stationary and the PVC couplers were lifted vertically, allowing the ground grain to flow downward, resulting in a pile on top of the plate. The height of the pile was measured, and angle of repose was calculated by the following equation, Angle of repose = $\tan^{-1}$ (the height of the pile divided by one half the known diameter of the plate). A larger angle of repose represents a steeper slope and poorly flowing ground grain product; a low angle of repose would represent a freer flowing product. All data were analyzed using PROC MIXED in SAS 8.1. Particle size and added fat were modeled as continuous variables with mill type as a categorical value. Parameter estimates were then output to develop the regression equations that depend on particle size, added fat, and mill type. Graphs showing modeled data were then generated.

Experiment 1. The objective was to evaluate the effects of mill type, particle size, and added fat on the flow ability of ground corn. Six different particle size samples were ground by either a hammer mill or roller mill. The particle size mean and standard deviation for the corn ground with a roller mill and hammer mill were determined (Table 1). All samples were dried 12 hours to equalize moisture content. Soy oil was then added at 0, 2, 4, 6, and 8% to portions of each sample, to give a total of 60 samples (2 mill types, 6 particle

sizes, and 5 levels of added fat). Angle of repose was replicated six times within each sample.

Experiment 2. The objective was to determine if the flow differences between hammer mill ground grain and roller mill ground grain were due to the particle size standard deviation. Samples of roller mill and hammer mill ground corn were sifted with a Ro-Tap tester through a stack of 13 screens and material on top of each screen was collected. The screen number, particle size means, and particle size standard deviations for five samples of corn ground with the roller mill and five samples of corn ground with a hammer mill were determined (Table 2). Soy oil was then added at 0, 4, and 8% to portions of each sample, to give a total of 30 samples (2 mill types, 5 particle sizes, and 3 levels of added fat). Angle of repose was replicated six times within each sample.

Experiment 3. The objective was to further evaluate if the flow differences between hammer mill and roller mill ground grain were due to the particle size standard deviation. Samples of both roller mill and hammer mill corn were sifted through 13 screens, and material from each individual screen was collected. Four roller mill samples and four hammer mill samples were constructed from the grain collected to produce samples with similar particle size with increasing particle size standard deviations. The roller mill and hammer mill sample particle size and particle size standard deviations were determined (Table 3). Soy oil was then added at 0, 4, and 8% to portions of each sample, to give a total of 24 samples (2 mill types, 4 particle size standard deviations, and 3 levels of added fat). Angle of repose was replicated four times within each sample.

Results and Discussion

In Experiment 1 there was a three-way interaction ($P<0.05$) between particle size, added fat, and mill type (Figure 1). As particle size decreased and more fat was added, angle of repose increased, roller mill ground corn had a lower angle of repose than hammer milled ground grain. However, the difference between mill types, and amount of added fat, was less as particle size decreased. Corn ground with a hammer mill without added fat had a similar angle of repose to corn ground with a roller mill that had 6% added fat.

In Experiment 2 there was a three-way interaction ($P<0.05$) between particle size, added fat, and mill type (Figure 2). The angle of repose increased as particle size decreased and added fat increased. However as particle size decreased, the angle of repose increased at a greater rate in hammer mill samples compared to roller mill samples.

In Experiment 3 there was no interaction ($P>0.10$) between PSSD, added fat, and mill type. Increasing fat ($P<0.04$) and PSSD ($P<0.001$) decreased flow ability (Figure 3). When particle size and standard deviation are equal, mill type appears to have no influence on the flow ability of the ground corn. However, because of the differences in how particle size is reduced between types of mills, grain ground with a hammer mill very frequently will have a greater standard deviation than grain ground to the same mean particle size with a roller mill.

In conclusion, these data suggest that the greater flow ability of roller mill ground corn appears to be largely a result of less particle size variation when compared to corn ground with a hammer mill. At fine particle sizes, particle shape also appears to contribute to differences in the flow ability of corn ground through roller mills or hammer mills. Our experiments suggest that flow ability is influenced by particle size standard deviation, particle size, and added fat.

Table 1. Particle Size and Standard Deviation (Experiment 1)[a]

Sample #	Roller Mill	Hammer Mill
1	1235 (1.98)	984 (2.56)
2	887 (1.83)	980 (2.52)
3	848 (1.84)	931 (2.49)
4	747 (2.03)	665 (2.49)
5	505 (1.99)	477 (2.25)
6	502 (1.97)	390 (2.12)

[a]Values represent the mean of one sample analyzed in duplicate.

Table 2. Particle Size and Standard Deviation (Experiment 2)[ab]

Sample #	Sieve #	Roller Mill	Hammer Mill
1	16	1415 (1.09)	1382 (1.12)
2	20	995 (1.16)	952 (1.20)
3	30	702 (1.17)	686 (1.20)
4	40	496 (1.19)	484 (1.19)
5	50	343 (1.20)	333 (1.29)

[a]Values represent the mean of one sample analyzed in duplicate.
[b]Each sample was collected from the material on top of the screen, to minimize particle size standard deviation.

Table 3. Particle Size and Standard Deviation (Experiment 3)[ab]

Sample #	Roller Mill	Hammer Mill
1	679 (1.62)	662 (1.62)
2	674 (1.89)	641 (1.88)
3	667 (2.10)	653 (2.12)
4	673 (2.22)	670 (2.27)

[a]Values represent the mean of one sample analyzed in duplicate.
[b]Samples were constructed to have similar particle size, from the grain collected on top of the 13 screens.

Legend for Figures 1, 2, and 3

0% added fat, hammer-milled	0% added fat, roller-milled
3% added fat, hammer-milled	3% added fat, roller-milled
6% added fat, hammer-milled	6% added fat, roller-milled

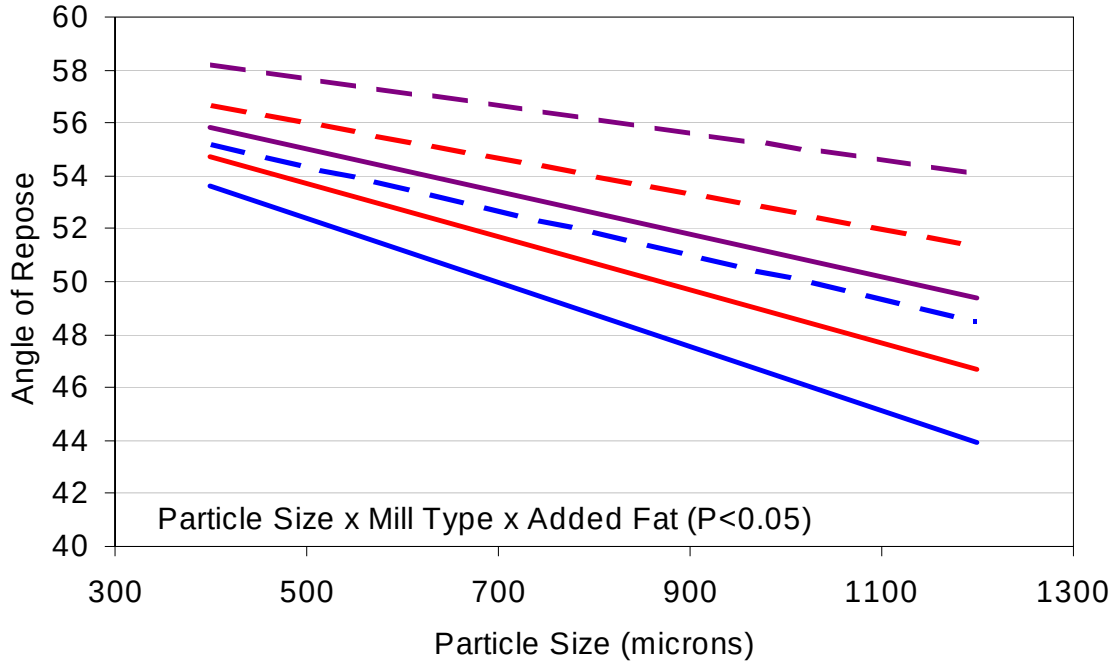

Figure 1. Effect of mill type, particle size and added fat on the flow ability of ground corn (Experiment 1).

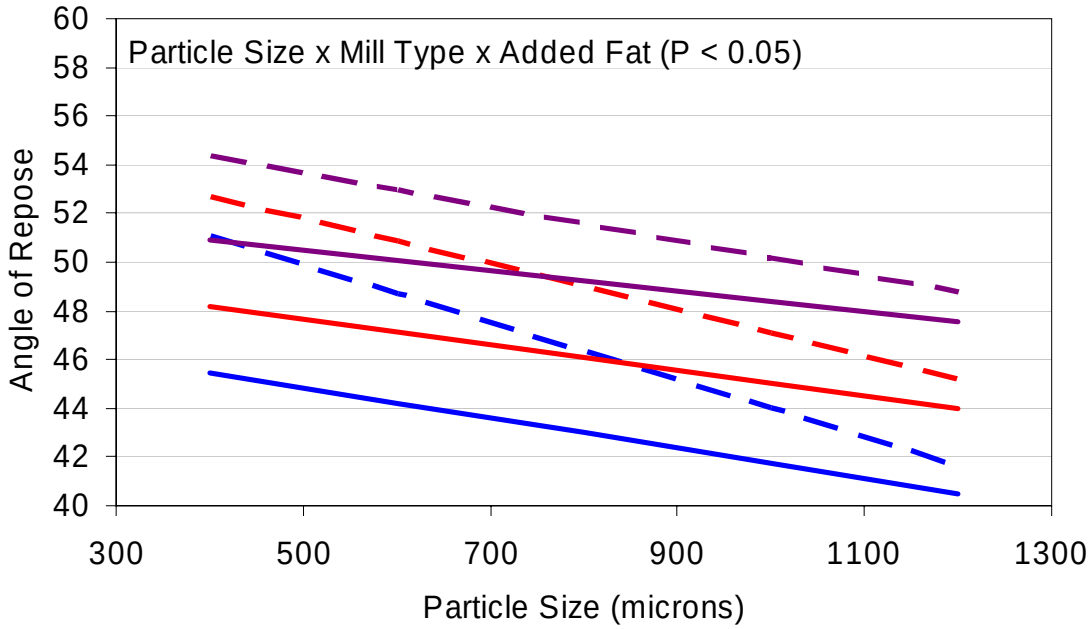

Figure 2. Effect of particle size with narrow particle size standard deviation (1.1 to 1.3) on ground grain flow ability (Experiment 2).

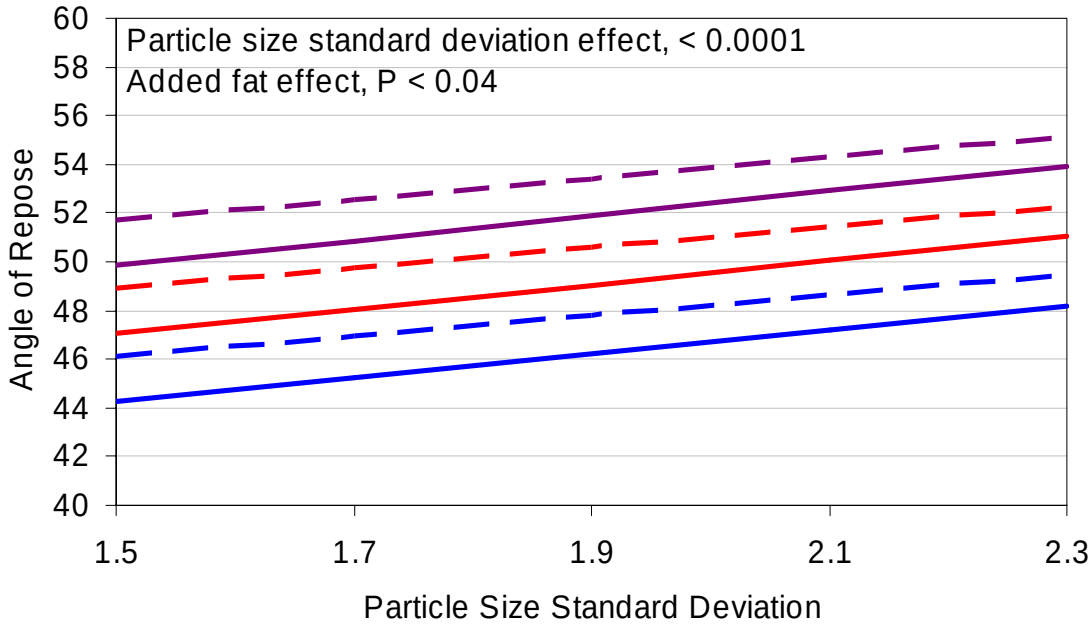

Figure 3. Effect of particle size standard deviation on ground grain flow ability. The average particle size equal to 665 microns with increasing particle size standard deviation (Experiment 3).

Swine Day 2003

THE INFLUENCE OF CHOP LOCATION ON PORK LOIN QUALITY[1]

J.W. Homm, J.A. Unruh, and R.C. Johnson[2]

Summary

Pork longissimus muscle quality characteristics were evaluated on 109 center cut boneless loins. After 21 d aging, loins were cut into 1-inch chops and allowed to bloom for 30 minutes before visual measurements (color, marbling and firmness) and instrumental color were recorded for each chop. Overall, visual color was the lightest on the anterior and posterior ends and was the darkest from approximately 50% to 80% of the length of the loin. Marbling was the highest at the posterior end, lowest in mid-loin, then higher toward the anterior end. Loins were the softest at the anterior end and became firmer toward the posterior end.

From the anterior to approximately 40-50% of the loin length, chops became darker (lower L*), redder (higher a*), and less yellow (lower b*). Near the center of the loin, color was constant, but became lighter (higher L*) and more yellow (higher b*) at the posterior end.

Chops located at 25% (anterior), 50% (middle) and 75% (posterior) of the length of each loin were collected and further analyzed. Section chops within loins had similar pH values. The chop from the anterior section contained the highest percentage of crude fat, followed by the posterior section chop, and the middle section chop contained the lowest percentage. The middle section chop contained the highest percentage of moisture. The posterior section chop had more moisture display loss than the anterior and middle section chops. The anterior section chop had more cooking loss than the posterior section chop. Chops became progressively less tender the more posterior the section location.

(Key Words: Chop Location, Pork Quality, Longissimus)

Introduction

Pork quality and consistency is important to consumers. Fresh pork color, tenderness, cooking loss, display loss, fat, moisture and pH are all contributing characteristics. Production, slaughter, chilling, retail, and cooking variables can affect these characteristics. In addition, variation within a pork loin may contribute to inconsistency of quality. Previous research conducted at Kansas State University showed considerable variation of pork quality within the same loin. The objective of this experiment was to further investigate the variation of pork quality characteristics within a loin.

Procedures

One-hundred-nine center-cut boneless pork loins (seventh rib through the sixth lumbar vertebra) were obtained from a commer-

[1]The authors thank Triumph Pork for their financial support.
[2]Director of Pork Quality, Triumph Pork Group.

cial packing facility on four different days (n=31, 32, 31, and 15). After aging for 21 days, loins were cut into 1-inch chops, from anterior to posterior, and allowed to bloom for 30 minutes.

Using the NPPC Official Color and Marbling Standards (1999), subjective color and marbling scores were assigned to the longissimus muscle of each chop. Visual color was evaluated on a 1 to 6 scale, with 1 representing a pale pinkish-gray to white and 6 representing a dark-purplish red color. Visual marbling was evaluated on a scale corresponding to the predicted percentage of intramuscular lipid content. Firmness was evaluated on a scale of 1 to 3 to the nearest 0.5, with 1=very soft and 3=very firm.

Each chop was also scanned with a HunterLab Miniscan™ XE Spectrophotometer (Hunter and Associates, Reston, VA) with a 1.25 in aperture under illuminant C, to obtain L*, a* and b* values. Each chop was scanned at two locations (lateral and medial) within the longissimus muscle and averaged. The L* value is a measure of darkness to lightness. The a* value is a measure of green to red, and the b* value measures blue to yellow.

The pair of chops closest to 25% (anterior), 50% (middle) and 75% (posterior) of the length of the loin was collected. The anterior chop at each location was analyzed for crude fat, moisture and pH. Crude fat and moisture were preformed using the CEM by AOAC (1999) procedures. Using the procedures from "The handbook for meat chemists," pH was measured. The posterior chop at each location was weighed and placed into a diapered styrofoam tray, overwrapped to simulate retail conditions, and displayed under fluorescent lighting in open-top display cases. Case temperature (34 to 36°F) was monitored using temperature data loggers. Following a 24 hour display period, instrumental color and final display weights were recorded, and each chop was cooked to an internal temperature of 158°F in a Blodgett dual-air-flow oven. While cooking, temperature was monitored using thermocouples attached to a Doric Minitrend 205 temperature monitor. Chops were cooled at room temperature for 20 minutes and reweighed. Finally, chops were chilled for 24 hours at 38°F before six 0.5-inch cores were taken parallel to the muscle fibers and sheared perpendicular to the muscle fibers using a Universal Instron with a Warner Bratzler attachment.

For analysis, all data were blocked by loin. To standardize chop location within a loin for regression analysis, chops were assigned a percentage of loin length location and rounded to the nearest five percent.

Results and Discussion

Visual measurements for chops taken after 30 minutes bloom are reported in Figure 1. Both a linear and quadratic relationship ($P<0.05$) was observed for visual color from the anterior to the posterior loin. Visual color was the lightest in the anterior quadrant and increased towards the middle of the loin. Color was darkest from approximately 50 to 75% of the length of the loin before decreasing towards the posterior end. The quadratic regression model had an R^2 of 0.83. Visual marbling had both a linear and quadratic relationship ($P < 0.05$) from the anterior to the posterior loin. Visual marbling was the highest on the anterior and posterior ends and was the lowest at approximately 50% of the length of the loin. The quadratic regression model for marbling had an R^2 of 0.81. Visual firmness had a linear increase ($P<0.05$) from anterior to posterior. The linear model had an R^2 of 0.97.

Instrumental values for color (L*, a*, b*) taken after 30 minutes of bloom are presented

in Figure 2. Instrumental L* and b* measurements had both linear and quadratic relationships (P<0.05) from the anterior to the posterior end of the loin. The L* value was the lightest at the anterior end and was progressively darker to approximately 50% of the length of the loin, then again was lighter toward the posterior end. The quadratic regression model for L* had an R^2 of 0.79. The a* value was the lowest at the anterior quadrant, increased in redness toward the middle of the loin, and then remained constant toward the posterior end. The quadratic regression model for a* had an R^2 of 0.85. For b* a linear relationship did not exist (P=0.67), but a significant quadratic relationship existed (P<0.05). The b* value was the most yellow at the anterior end, decreased toward the middle of the loin and then increased again toward the posterior end. The quadratic model had an R^2 of 0.61.

Visual and instrumental values suggest that chops from the anterior and posterior end are lighter in color than chops from the middle of the loin. Instrumental values also indicate that the anterior end is lighter, less red, and more yellow. The posterior end of the loin begins to lighten and become more yellow than the center loin region.

Influence of chop location on pork quality traits at three loin locations are presented in Table 1. Location of chops did not affect pH (P=0.48). Crude fat content was the highest in the anterior section chop and lowest in the middle section chop (P<0.05). Moisture content was similar in the anterior and posterior section chops (P=0.13) and slightly higher (P<0.05) in the middle section chop. After 30 minutes of bloom, chops were progressively lighter in the anterior section chop to the posterior section chop (L*, P<0.05), and chops were more red from the posterior chop section to the anterior chop section (a*, P<0.05). The anterior and posterior section chops were more yellow than the middle section chop (b*, P<0.05). The anterior section chop was the lightest after 24 hour display. The middle section chops were redder (a*, P<0.05) than the anterior section chops after 24 hours of display. Yellowness (b*) was the higher (P<0.05) in the posterior section chops compared to the anterior section chops. Display moisture loss was the highest in the posterior section chop (P<0.05), and the anterior and middle section chops were similar (P=0.18). Cooking loss was higher (P<0.05) at the anterior section location than the posterior section location, and the middle section chop was intermediate. The anterior section chop was the most tender followed by the middle, then the posterior section chop (P<0.05).

Location within a pork loin affects quality characteristics. Within a loin, variation in visual color, instrumental color, chop composition and cookery traits were observed. Packaging chops by sections of the loin could improve the consistency of pork quality.

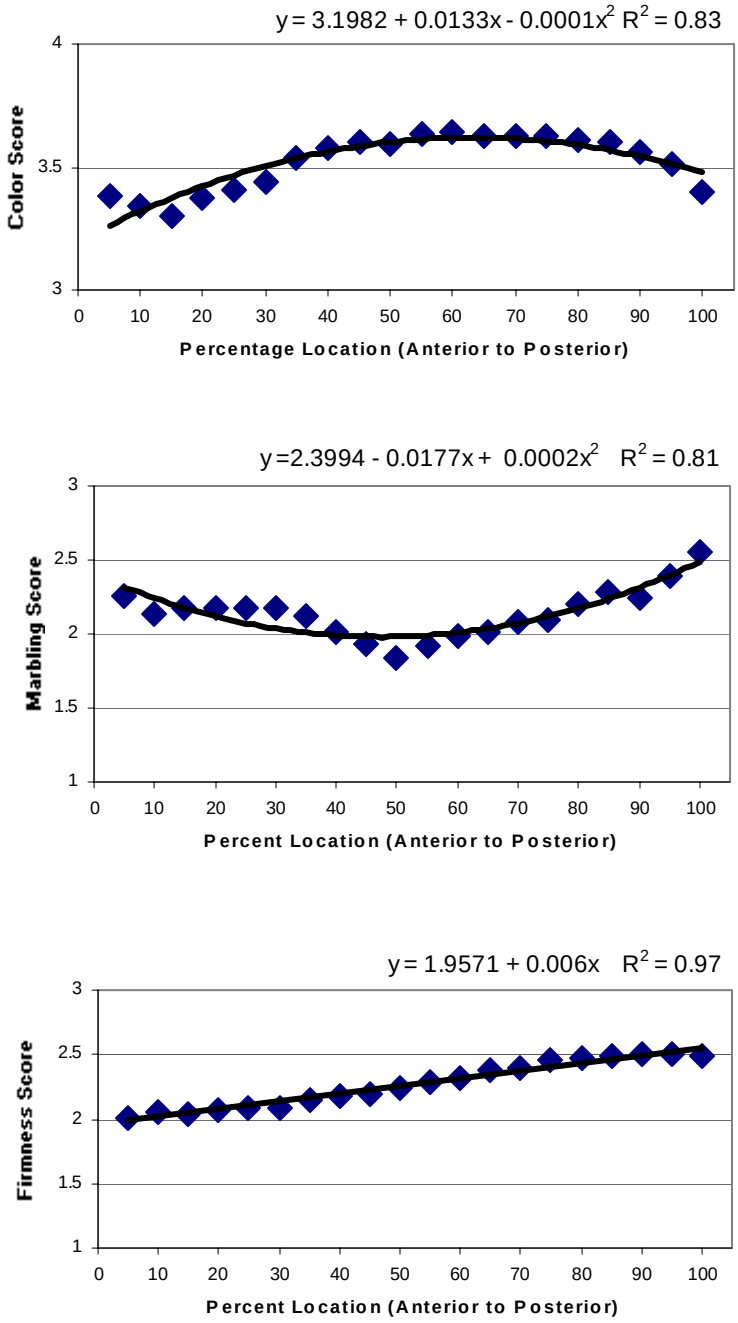

Figure 1. Influence of chop location (%) within a center cut boneless loin on visual measurements. Visual color (3=reddish pink and 4=dark reddish pink) and marbling (corresponding to intramuscular lipid content) were evaluated using NPPC Official Color and Marbling Standards (1999). Firmness was evaluated on a scale of 1 to 3 to the nearest 0.5 with 2= slightly firm and 3=very firm.

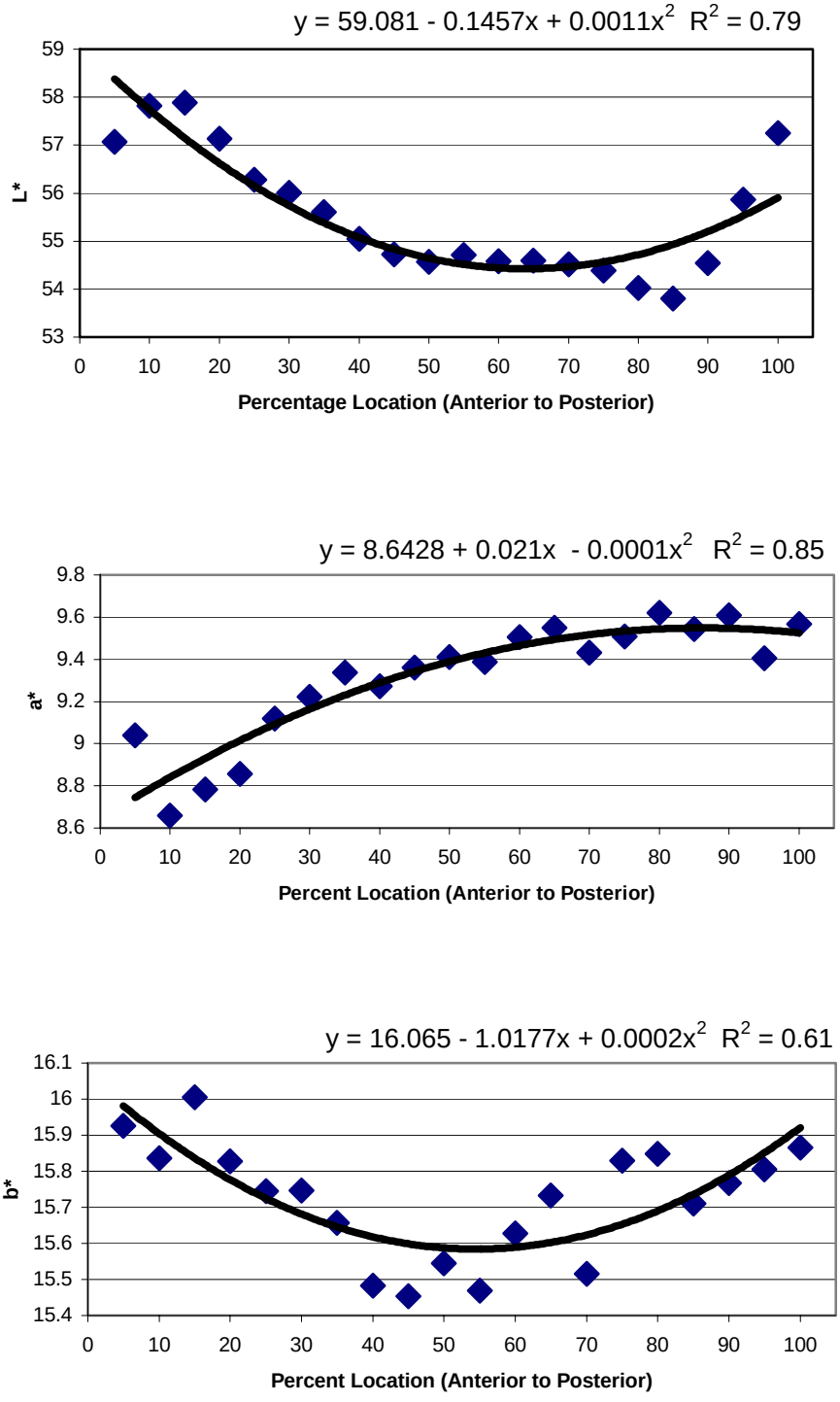

Figure 2. Influence of chop location (%) within a center cut boneless loin on instrumental color.

Table 1. Influence of Chop Location within a Center Cut Boneless Loin on Pork Quality

	Chop Location[a]			
Item	Anterior	Middle	Posterior	SE[b]
pH	5.72	5.73	5.73	0.02
Crude Fat, %	1.93[e]	1.35[f]	1.59[g]	0.08
Moisture, %	73.36[e]	73.76[f]	73.43[e]	0.07
Instrumental Color[c], 30 min				
L*	56.21[e]	54.69[f]	53.99[g]	0.30
a*	9.17[e]	9.39[f]	9.61[g]	0.12
b*	15.74[e]	15.48[f]	15.85[e]	0.12
Instrumental Color[c], 24 h				
L*	51.67[e]	50.19[f]	50.15[f]	0.31
a*	11.12[e]	11.40[f]	11.23[ef]	0.13
b*	17.42[e]	17.47[ef]	17.60[f]	0.11
Display loss, %	0.83[e]	0.87[e]	1.06[f]	0.03
Cooking Loss, %	21.96[e]	21.05[ef]	20.18[f]	0.40
WBS[d], lb	6.14[e]	6.62[f]	7.00[g]	0.12

[a]Anterior, middle and posterior represent 25, 50, and 75% of the length of the loin, respectively.

[b]Standard error.

[c]Instrumental color was measured using HunterLab Miniscan (Illuminant C with a 1.25 in aperture).

[d]Warner-Bratzler Shear (average of six, 0.5 in cores from chops cooked to 158°F).

[e,f,g]Means in the same row without a common superscript differ ($P<0.05$).

INDEX OF KEY WORDS

Indexer's note: The numbers refer to the first pages of each article that uses the listed key word.

Added Fat (159, 203)
ADG (164)
Amino Acids (47, 56)
Antibiotic (132)
Antibiotics (115, 119, 123)
Antimicrobial(s) (123, 128)
Backfat (19)
BioPlus 2B (136)
Body Condition Score (19)
Calcium (171)
Carbadox (111)
Carcass (155)
Carnichrome® (7)
Carnitine (1)
Chicory (193)
Chop Location (209)
Corn (176)
Crystalline Amino Acids (150)
Digestibility (33, 36)
Disease Challenge (136, 141)
Distiller's Dried Grains with Solubles (185)
Energy (176, 185)
Energy Density (164)
Enzyme (146)
Fat (56, 71, 155, 176)
Feed Additive (106 111, 115, 119)
Finishing (155)
Finishing Pigs (56, 171)
Fishmeal (97, 102)
Gestation (7)
Growing Pigs (150)
Grow(ing)-Finish(ing) Pigs (159, 164, 176)
Growth (39, 43, 47. 67, 71)
Growth Performance (56)
Hammer Mill (203)
Heat Production (7)
Hemicell® (146)
Insulin-like Growth Factor (1)
Irradiation (106)
Lactation (33, 36)
Longissimus (209)
Lysine (61, 67)
Lysine Requirement (39, 43)
Mannanoligosaccharides (128)
Net Energy (47)
Nursery (77, 132)
Nursery Pig (39, 43, 106, 111, 115, 119)
Nursery Pigs (61, 128)
Nutrient Excretion (193)
Odor (193)
Particle Size (36, 141, 203)
Pellet(ing) (33, 141)
Performance (90, 150)
Phase II (43)
Phosphorus (171)
Phytase (171, 193)
Pigs (67, 71, 77, 185, 193)
Plasma (77)
Pork Quality (209)
Poultry Meal (97, 102)
Roller Mill (203)
Saccharomyces cerevisiae (136)
Salmonella (136, 141)
Sow (33, 36)
Sows (1, 7, 19)
Soybean Meal (77, 90)
Synthetic Amino Acids (71)
Threonine (61)
Transition Diet (39)
Weanling Pigs (90, 97, 102, 123, 136, 141, 146)
Whey (77)
Yeast (132)

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