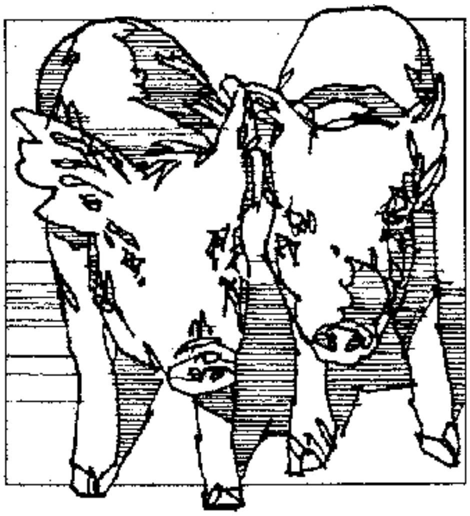

KANSAS
STATE
UNIVERSITY

SWINE DAY 1993

REPORT OF PROGRESS 695, AGRICULTURAL EXPERIMENT STATION, MARC A. JOHNSON, DIRECTOR

FOREWORD

It is with great pleasure that we present to you the 1993 Swine Day Report. This report contains summaries of applied and basic swine research conducted at Kansas State University during the past year. Topics range from economics to physiology and nutrition. We hope that the information will be of benefit, as we attempt to meet the needs of the Kansas swine industry.

Editors, 1993 Swine Day Report,

Bob Goodband Mike Tokach

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
cwt = 100 lb
d = day(s)
DM = dry matter
°F = Fahrenheit
F/G = feed efficiency
ft = foot(feet)
ft^2 = square foot(feet)
g = gram(s)
gal = gallon(s)
h = hour(s)
in = inch(es)
IU = international unit(s)
kg = kilogram(s)
Kcal = kilocalorie(s)
lb = pound(s)
Mcal = megacalorie(s)
mEq = milliequivalent(s)
min = minute(s)
mg = milligram(s)
ml = cc (cubic centimeters)
mo = month(s)
µg = microgram(s) = .001 mg
N = nitrogen
ng = nanogram(s) = .001 µg
no. = number
ppm = parts per million
sec = second(s)
wk = week(s)
wt = weight(s)
yr = year(s)

KSU VITAMIN AND TRACE MINERAL PREMIXES

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

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

Vitamin premix: each lb of premix contains vitamin A, 2,000,000 IU; vitamin D_3, 200,000 IU; vitamin E, 8,000 IU; menadione, 800 mg; riboflavin, 1,500 mg; pantothenic acid, 5,200 mg; niacin, 9,000 mg; choline, 30,000 mg; and vitamin B_{12}, 6 mg.

Sow add pack: each lb of premix contains choline, 70,000 mg; biotin, 40 mg; and folic acid, 300 mg.

NOTICE

Kansas State University makes no endorsement, expressed or implied, of any commercial product. Trade names are used in this publication only to ensure clarity of communication.

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.

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Gestation, Breeding, and Farrowing Management

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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<.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 ± .1. The 2.5 is the average; .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.

EMBRYONIC SURVIVAL AND VARIATION IN EMBRYONIC DEVELOPMENT ON DAY 11 OF GESTATION

R. M. Blair, C. M. Coughlin,
J. E. Minton, and D. L. Davis

Summary

The primary objective of this study was to determine if embryo survival in gilts and primiparous sows was related to variations in the periovulatory profiles of estradiol-17β, progesterone, and luteinizing hormone. A secondary objective was to compare embryo development and certain endocrine characteristics in gilts and primiparous sows. Sows (n=6) and gilts (n=6) were catheterized in the jugular vein on the day after weaning and day 14 of the estrous cycle, respectively. Additional females (1 gilt and 7 sows) were examined for characteristics of embryonic development, but blood samples were not collected. Embryo size and volume on day 11.5 to 11.75 of gestation were recorded. Embryo recovery was 71.4% based on the number of corpora lutea. Minimal differences were observed between sows and gilts for endocrine and embryo data. However, endocrine differences were noted for pigs with high embryo survival (> 71% recovery) compared to those with low survival. Peak estradiol-17β occurred closer to the onset of estrus in pigs with high embryo survival than in pigs with low embryo survival, and peak LH occurred later after the onset of estrus for pigs with high embryo survival. Also, pigs with high embryo survival tended to have less variation in embryonic development than those with low embryo survival. These data suggest that increased embryo survival and decreased diversity in development might be associated with a closer synchrony between the onset of estrus and peak concentration of estradiol-17β.

(Key Words: Pig, Embryo Survival, Hormone.)

Introduction

Embryonic diversity within litter, implicated as a cause of embryo mortality in swine, has been the emphasis of several studies. Morphological and biochemical variations in follicular development have been observed in swine, and it is hypothesized that embryonic diversity and subsequent embryo mortality are the result of variation in the rate of follicular development and ovulation.

Previous research has indicated that primiparous sows have lower percentages of fertilized eggs than multiparous sows. Therefore, anomalies in the periovulatory endocrine environment might be associated with fertilization failure and/or early embryonic death in pigs; however, no data are available currently that examine this possible association. The primary objective of the present study was to determine whether embryonic diversity and the proportion of ovulations represented by embryos on d 11 were associated with periovulatory endocrine events. A secondary objective was to evaluate embryonic diversity and embryo survival in gilts and primiparous sows on d 11 of pregnancy.

Procedures

Crossbred (Hampshire × Chester White × Yorkshire × Duroc) gilts (n=6) and primiparous sows (n=6) were fitted with jugular catheters on d 14 of the estrous cycle and the day after weaning, respectively. Both catheterized pigs, as well as additional pigs (1 gilt and 7 sows) not sampled for endocrine data, were examined for differences in embryonic development. Gilts and sows were checked for estrous behavior 3×/d (2:00 a,m., 10:00 a.m., and 6:00 p.m.) with an intact boar but were separated physically from boars at other times. Females were inseminated artificially with mixed semen from two boars at 16, 24, and 32 h after the observed onset of estrus.

Blood samples were collected twice daily (6:00 a.m. and 6:00 p.m.) until day 17.5 of the estrous cycle in gilts and day 3.5 postweaning in sows. Thereafter, frequency of blood sampling was increased to 4-h intervals until 24 h after the onset of estrus. Blood samples were collected subsequently twice daily until d 5 after estrus. Blood samples were stored overnight at 4°C and then serum was collected. Serum was analyzed for estradiol-17β (E_2), progesterone (P_4), and luteinizing hormone (LH) by radioimmunoassay.

Embryos were recovered surgically from all pigs on day 11.5-11.75 of gestation (d 0 = onset of estrus). The number, size, and volume of individual embryos were recorded after recovery. To determine variations in embryonic development, the average deviation from the mean embryo volume was calculated within litter as a percentage of the mean embryo volume.

Results

Using the number of CL as an estimate of ovulation rate, mean embryo recovery for all pigs was 71.4%. Therefore, for statistical analyses, pigs with > 71% embryo recovery were defined to have high embryo survival (mean embryo recovery = 86.61%), whereas pigs with < 71% embryo recovery were defined to have low embryo survival (mean embryo recovery = 52.77%).

Differences in the characteristics of the E_2 and LH (but not P_4) profiles were evident between pigs with high and low embryo survival (Table 1). Peak E_2 occurred later ($P<.05$) relative to the onset of estrus in pigs with high embryo survival. On average, peak E_2 occurred after estrus in pigs with high embryo survival and before estrus in pigs with low embryo survival. Furthermore, for all animals, embryo survival increased as the interval from estrus to peak E_2 increased ($r=.64$; $P<.05$). Peak LH occurred later ($P<.05$) after the onset of estrus in pigs with high embryo survival compared to pigs with low embryo survival. This was consistent with a positive association between the length of the interval from estrus to peak LH and embryo survival ($r=.65$; $P<.05$). Peak E_2 tended ($P=.07$) to be higher in pigs with low embryo survival compared to pigs with high embryo survival. The onset of the LH surge differed ($P<.05$) for pigs with high vs low embryo survival and occurred prior to peak E_2 in pigs with high embryo survival but after peak E_2 in pigs with low embryo survival.

No differences were evident in P_4 profiles between gilts and sows; however, differences were detected in E_2 and LH profiles (Table 1). Peak LH occurred nearer ($P<.01$) to the onset of estrus in gilts than sows, and the onset of the LH surge occurred earlier ($P<.05$) before estrus in gilts compared to sows. Peak E_2 and peak LH both tended ($P=.08$ and $P=.11$, respectively) to be greater in gilts compared to sows. Other characteristics of the E_2 and LH profiles were similar between gilts and sows; however, gilts tended ($P=.11$) to have a greater interval from peak LH to the end of the LH surge compared to sows.

No differences in ovulation rate and embryo volume were evident between pigs with high and low embryo survival (Table 1); however, pigs with high embryo survival tended ($P=.10$) to have less variation in embryonic development compared to pigs with low embryo survival. Evaluation of the data from all animals supports this association, because a negative correlation within litter occurred between embryo survival and the percent deviation in embryo development ($r=-.79$, $P=.0001$).

Discussion

In the present study, ovulation rate, embryo diversity, and embryo survival were similar between gilts and sows, indicating that fertility was not reduced in primiparous sows. In contrast, previous studies reported that fertilization rate was lower and litter size declined at the second farrowing. Data from our study indicate that the population of primiparous sows we used had fertility similar to that of gilts.

In our study, differences were noted in the LH and E_2 profiles between pigs with high versus low embryo survival. Previous research has indicated that disparity in the time of ovulation and zygotic maturation might be the result of skewed follicular development, in which the majority of follicles was more developed than the minority at 21-34 h after the onset of estrus. It has been suggested that a small group of follicles on d 18 of the estrous cycle secrete E_2 sooner than other follicles and induce the ovulatory surge of LH. This series of events would result in the ovulation of follicles at different maturational stages, thus, possibly contributing to diversity in embryonic development. Variation in embryo size in pigs appears to be greatest on days 11 and 12 of gestation, which correspond to the stage of development evaluated in the present study.

In our study, pigs with high embryo survival on d 11.5 to 11.75 of gestation tended to exhibit less variation in embryonic development than pigs with low embryo survival. Embryo losses in our experiment might have been due to fertilization failures or embryo death before day 11. Perhaps both embryo diversity and embryo loss before day 11 result from the same causes.

In conclusion, results of the present study suggest that a closer synchrony among peak E_2, the onset of the LH surge, and estrus is associated with reduced embryo diversity and higher embryo survival prior to implantation. Perhaps embryo survival could be improved by changing the timing of preovulatory endocrine events.

Table 1. Periovulatory Endocrine Characteristics (Mean ± S.E.M.) and Embryo Development (Day 11.5; Mean ± S.E.M.) in Pigs with High (>71%) versus Low (<71%) Embryo Recovery and in Gilts versus Sows

	Embryo Survival		Parity	
Characteristic	High	Low	Gilt	Sow
Endocrine Traits				
No. of pigs	7	5	6	6
Onset of estrus to:				
Peak E_2, h	3.33[c]	-13.00[d]	-4.67	-5.00
Peak LH, h	11.33[c]	5.00[d]	3.33[e]	13.00[f]
Peak E_2, pg/ml	28.17	35.21	35.01	28.37
Peak LH, ng/ml	7.01	6.35	8.36	5.00
Onset of LH surge relative to peak E_2, h	-5.83[c]	6.33[d]	-4.00	4.50
Onset of LH surge relative to estrus, h	-2.50	-6.67	-8.67[e]	-0.50[f]
Embryo Traits				
No. of pigs	11	9	7	13
Embryo recovery, %	86.61	52.77	69.26	70.00
Ovulation rate	15.88	17.25	15.88	17.25
Embryo volume, mm^3	403.04	368.12	414.43	356.72
Average deviation of embryo volume, mm^3 [a]	162.45	189.84	180.13	172.16
Average deviation as % of mean embryo volume[b]	40.76[g]	59.39	50.14	50.01

[a] The mean conceptus volume was determined for each litter, and the absolute value of the deviation from the mean was determined for each conceptus. The average deviation within each litter was used as a measure of the diversity in size within the litter.

[b] Calculated as in footnote a, except that each deviation was converted to a percent of the mean conceptus volume for the litter.

[c,d] Different superscripts within rows between high versus low embryo survival are significantly (P<.05) different.

[e,f] Different superscripts within rows between gilt versus sow are significantly (P<.05) different.

[g] Tends (P=.10) to be less than for pigs with low embryo survival.

VALINE: A LIMITING AMINO ACID FOR HIGH-PRODUCING LACTATING SOWS[1]

M. D. Tokach, R. D. Goodband, and J. L. Nelssen

Summary

A total of 152 lactating sows was used to determine the influence of dietary valine level on sow and litter performance. During lactation, sows were fed corn-soybean meal based diets containing .9% lysine and either .75 or .9% valine. Lactation diet had no influence on litter birth weight, pig survivability, pigs weaned per litter, or daily sow feed intake. However, sows fed the .90% valine diet had increased pig and litter weaning weights. These differences were magnified as number of pigs weaned and sow milk production increased. These results indicate that further research is needed to determine the valine requirement of the high-producing sow. However, the practical implication of this trial is that valine deficiencies limit the amount of synthetic lysine that can be used in high protein diets for the lactating sow.

(Key Words: Valine, Amino Acids, Sows.)

Introduction

Recent research at Kansas State University, University of Kentucky, and University of Minnesota suggests that the lysine requirement of the high-producing sow is much greater than listed by NRC (1988). This change in lysine recommendations has led to questions concerning the requirement of other amino acids. We typically use an ideal amino acid ratio to determine the requirement for other amino acids based on lysine. The amino acid ratios suggested by NRC (1988) and ARC (1981) are used most often (Table 1). The ARC ratio is based on the composition of milk, whereas the NRC ratio was developed from feeding trials. These ratios are similar for all amino acids except valine.

Table 1. NRC and ARC Amino Acid Ratios for Lactating Sows

Amino Acid	ARC Ratio	NRC Ratio	% Diff
Lysine	100	100	0
Isoleucine	70	65	7
Met & Cys	55	60	9
Threonine	70	72	3
Tryptophan	19	20	5
Valine	70	100	43

The reason that the valine to lysine ratio is important is that, according to the NRC ratio, valine is the second limiting amino acid in high protein diets for the lactating sow. If 3 lb of synthetic lysine is added to the diet, valine actually is the first limiting amino acid using the NRC ratio. However, valine is not a concern using the ARC ratio. Therefore, this experiment was designed to determine if the valine to lysine ratio suggested by ARC (1981) is too low.

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[1] Appreciation is expressed to Nutri-Quest, St. Louis, MO for providing amino acids for this study. The authors also wish to thank Phillips Farm, Drexel, MO for data collection and use of facilities and animals.

Procedures

On a commercial swine operation, 152 lactating sows were randomly allotted at farrowing to the experimental diets. Diets were formulated to contain .9% lysine and .75 or .9% valine giving valine to lysine ratios of .83:1 and 1:1, respectively (Table 2). L-valine replaced corn to formulate the high valine diet. All other amino acids were fortified at 105% of the ratio suggested by NRC (1988) (Table 3). Diets were corn-soybean meal-based and contained equal amounts of all synthetic amino acids except valine. Diets were calculated to contain .9% Ca and .8% P.

Table 2. Composition of Diets, %

Item	Control	Valine
Corn	70.43	70.28
Soybean meal, 48%	16.78	16.78
Soybean oil	7.5	7.5
Dicalcium phosphate	2.76	2.76
Sodium bentonite	.50	.50
Limestone	.57	.57
Salt	.50	.50
Vitamin premix	.30	.30
Trace mineral premix	.20	.20
L-Lysine HCl	.255	.255
L-Valine	—	.15
L-Threonine	.107	.107
DL-Methionine	.052	.052
L-Tryptophan	.033	.033
L-Isoleucine	.012	.012
Total	100	100

Litters were equalized by 24 h after farrowing. Litters were weighed at birth and weaning (21 ± 2 d after farrowing). Sows were provided ad libitum access to feed and water, and feed intake was recorded daily. Following weaning, sows were moved to a breeding facility and checked twice daily for signs of estrous. Days from weaning to estrous were recorded. This experiment was conducted from July 1 to October 25, 1992. Sows were housed in individual farrowing crates in environmentally controlled farrowing rooms. Flooring under the sow and creep area was plastic-coated expanded metal. The minimum air temperature in the farrowing room was 70°F. Drip coolers were activated when air temperature exceeded 80°F.

Table 3. Dietary Amino Acid Levels, %

Item	Control	Valine
Lysine	.90	.90
Valine	.75	.90
Threonine	.68	.68
Methionine	.30	.30
Met & Cys	.57	.57
Tryptophan	.19	.19
Isoleucine	.61	.61

Results

Lactation diet (.75 vs .90% valine) had no influence ($P > .45$) on litter birth weight (35.0 vs 34.9 lb), pig survivability (91.8 vs 92.7%), pigs weaned per litter (10.12 vs 10.25), and daily sow feed intake (9.2 vs 9.2 lb). However, sows fed the .90% valine diet had increased pig ($P < .09$) and litter ($P < .04$) weaning weights (Table 4). These differences were magnified as the number of pigs weaned and sow productivity increased (≤ 10 vs > 10 pigs).

Discussion

Increasing dietary valine from .75% to .90% resulted in a substantial increase in litter weaning weights. These results indicate that the ideal valine to lysine ratio is greater than .83:1 (.75% valine in a diet containing .90% lysine). Certainly, the ratio of .70:1 proposed by ARC (1981) from the amino acid composition of milk is too low. We are currently conducting further research to more closely determine the valine requirement of the high-producing sow.

The practical aspect of this research is the impact that it has on synthetic amino acid use in sow lactation diets. Previously, most nutritionists believed that the most limiting amino acids in corn-soybean meal diets for lactating sows were lysine, threonine, methionine, and tryptophan. Thus, a common recommendation was to use .15% L-lysine HCl in sow lactation diets. The impact of synthetic lysine on the order of limiting amino acids in sow lactation diets is demonstrated in Tables 5 and 6. For these tables, the NRC (1988) and ARC (1981) ratios were used to determine the deficient amino acids in corn-soybean meal diets formulated without (Table 5) or with (Table 6) L-lysine HCl. These tables demonstrate that the order of limiting amino acids changes as lysine levels increase. Lysine is the first limiting amino acid at the lower dietary lysine levels. However, at high lysine levels (> .90%), valine becomes the first limiting amino acid using the NRC (1988) ratio (Table 5). When synthetic lysine is used in formulation (Table 6), valine becomes limiting at a relatively low lysine level (.7%).

Our research indicates that valine deficiencies limit the use of L-lysine HCl in sow lactation diets and that diets formulated on predictions of amino acid requirements based on milk production and maintenance will underestimate the valine requirement of the lactating sow.

Table 4. Influence of Valine Level (.75 or .90%) in Sow Lactation Diet on Litter Performance

	All Sows		< 10 Pigs		> 10 Pigs		
Item	.75	.90	.75	.90	.75	.90	CV
No. of sows	75	77	39	39	36	38	--
No. of pigs weaned	10.12	10.25	9.21	9.28	11.18	11.17	10.5
Pig weaning wt, lb[a]	12.7	13.2	13.3	13.6	11.9	12.7	13.6
Litter weaning wt, lb[b]	127.0	134.0	122.0	125.8	133.4	141.4	15.3

[a] P<.09.
[b] P<.04.

Table 5. Amino Acid Ratios of Corn-Soybean Meal Diets

	Dietary Lysine, %				
Amino Acid	.60	.70	.80	.90	1.0
Lysine	100	100	100	100	100
Isoleucine	92	87	84	82	80
Methionine and Cystine	83	76	71	67	64
Threonine	88	83	79	77	74
Tryptophan	27	26	25	24	24
Valine	115	109	104	100	97[a]

[a] Deficient according to NRC (1988) amino acid ratio.

Table 6. Amino Acid Ratios of Corn-Soybean Meal Diets with 3 lb L-Lysine HCl

	Dietary Lysine, %				
Amino Acid	.60	.70	.80	.90	1.0
Lysine	100	100	100	100	100
Isoleucine	80	77	75	73	72
Methionine and Cystine	75	70	65	62	59[a]
Threonine	77	74	71[a]	69[a]	68[a,b]
Tryptophan	23	23	23	22	22
Valine	102	97[a]	94[a]	91[a]	89[a]

[a] Deficient according to NRC (1988) amino acid ratio.
[b] Deficient according to ARC (1981) amino acid ratio.

EXTRUSION OF SORGHUM GRAIN AND SOYBEANS FOR LACTATING SOWS

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J. D. Hancock, and T. L. Gugle

Summary

One hundred-seventeen primiparous sows were used to determine the effects of extruded sorghum grain and soybeans in lactation diets on sow and litter performance. The sows were fed a sorghum-soybean-based diet with the sorghum and soybeans extruded either singly or together. Treatments were: 1) ground sorghum-soybean meal (SBM)-soy oil-based control; 2) extruded sorghum-SBM-soy oil; 3) ground sorghum-extruded soybeans; and 4) sorghum and extruded soybeans blended then extruded together (extruded blend). All diets were formulated to .80% lysine, .90% Ca, .80% P, and 1.47 Mcal ME/lb. Sows fed diets with extruded ingredients tended to wean more pigs with greater survivability and greater litter weight gains compared to sows fed the ground sorghum-SBM-based control diet. No differences occurred in sow weight or sow backfat loss. Sows fed extruded soybeans had decreased sow weight loss (14.6 vs 29.7 lb) compared with those fed extruded sorghum. Overall, improvements in litter weight gain were 6, 7, and 10% for extruded sorghum, extruded soybeans, and the extruded blend, respectively, when compared to the ground sorghum-SBM-soy oil-based control. In conclusion, our data indicate that extrusion of ingredients for lactation diets improves sow and litter performance, and the greatest improvements were obtained by extrusion of blended soybeans and sorghum grain.

(Key Words: Process, Extrusion, Sorghum, Sows, Lactation.)

Introduction

The process of extrusion involves heat, pressure, and shear. Extruders are screw type augers in which high temperatures result from friction and pressure as the product is augured to the outlet. Extruders are capable of reaching temperatures up to 360°F, which is more than adequate to destroy trypsin inhibitors and other anti-nutritional factors present in soybeans. Extrusion also ruptures the oil cells of soybeans, allowing the oil to be reabsorbed onto the product and, thus, increasing digestibility. Extrusion affects cereal grains as well, by rupturing the semi-crystalline structure of starch granules, which causes gelatinization and, thus, enhances utilization by animals.

In the 1990 and 1991 KSU Swine Day Reports (Reports of Progress No. 610, page 76 and 641, page 92, respectively), it was reported that extrusion of sorghum and soybeans improved growth performance and nutrient digestibility by 5 to 20% in finishing pigs compared to feeding a ground sorghum-SBM-soy oil-based control. In the 1992 KSU Swine Day Report (Report of Progress No. 667, pages 65, 69, and 130), it was reported that the nutritional values of corn, sorghum, wheat, and barley were improved by extrusion of diets for finishing pigs. However, the use of extruded cereal grains in lactating sow diets has not been investigated. Therefore, an experiment was designed to determine the effects of extruded sorghum and(or) soybeans in lactation diets on sow and litter performance.

Procedures

On d 110 of gestation, 117 primiparous sows were randomly assigned to one of four experimental treatments (Table 1). The treatments were: 1) a ground sorghum-soybean meal (SBM)- soy oil-based control; 2) extruded sorghum-SBM-soy oil; 3) ground sorghum-extruded soybeans; and 4) sorghum and extruded soybeans blended then extruded together (extruded blend). Ingredients were extruded with an Insta-Pro Model 2000R dry extruder. The screw assembly consisted of four single-flight screws and seven double-flight screws (screw diameter of 5.25"). The screws were placed in series with the four single-flight screws at the inlet, followed by the seven double-flight screws. Spacer washers and steamlocks were placed between the screws as needed. The head assembly consisted of ribbed heads separated by wearsleeves. The same screw and head assembly was used to extrude all ingredients with the exception that the 5/16" nose cone was replaced by a "spaghetti" cutter head for extrusion of the sorghum grain. The sorghum was ground in a hammermill, and water was added to bring the sorghum to 18% moisture pre-extrusion. The extruded sorghum contained 2,350 lb of sorghum and 114 lb of water. Extrusion was at 1,240 lb/h with a final exit temperature of 256°F. The soybeans were ground through a roller mill before extrusion and extruded at 1,700 lb/hr with a final exit temperature of 300°F. The extruded blend was 2,096 lb sorghum, 904 lb extruded soybeans, and 146 lb water, with a final exit temperature of 172.6°F. Each diet was mixed in a 3,000 lb batch.

Sows were weighed and scanned ultrasonically for last rib fat depth at farrowing and at d 21 of lactation to determine weight and backfat loss. Piglet weights were recorded at farrowing and at d 21 to determine litter weight gain. Sow weight loss and backfat loss and litter weight gain were adjusted to a standard 21-d lactation. The sows were allowed ad libitum access to feed and water, and feed intake was recorded weekly. Response criteria were changes in sow weight and backfat during lactation, average daily feed intake (ADFI), and litter performance. All data were analyzed with sow as the experimental unit and initial litter size as a covariate.

Results and Discussion

No differences occurred in sow weight or backfat losses (P>.50) when the mean of extruded diets was compared to the sorghum-SBM-based control diet (Table 2). However, sows fed the extruded diets ate less feed (P<.01) than those fed the control diet. Sows fed the extruded blend had less weight loss (P<.05) than sows fed sorghum or soybeans extruded singly, and sows fed the extruded soybeans had greater ADFI (P<.05) and less weight loss (P<.001) than those fed extruded sorghum. The decreased ADFI for the extruded sorghum diet probably resulted from its flour-like consistency that reduced palatability, with the greatest decrease in feed intake occurring in the first week of lactation. Once the sows were acclimated to the extruded sorghum, their feed intakes were similar to those of sows fed the other diets.

Sows fed diets with extruded ingredients tended to wean more pigs (P<.10) because of the trend for greater piglet survivability during lactation (P<.15). Sows fed diets with extruded ingredients also tended to have heavier final litter weights and greater litter weight gain (P<.10). There were advantages of 4.4, 4.6, and 6.7 lb/litter for sows fed the extruded sorghum, extruded soybeans, and extruded blend, respectively, compared with sows fed the ground sorghum-SBM-soy oil-based control. These responses possibly resulted from the nutrients of extruded ingredients being more digestible. Improved digestibility of nutrients for extruded ingredients has been reported in previous KSU Swine Day Reports for both nursery and finishing pigs. However, we have yet to determine what the actual change in nutrient digestibility was in this experiment.

In conclusion, sows fed diets with extruded ingredients tended to have greater piglet survival and heavier litters, with decreased ADFI compared to those fed the control diet. Among sows fed diets with extruded ingredients, those fed the extruded blend has less weight loss during lactation than sows fed extruded sorghum or soybeans. However, cost of extrusion must be taken into consideration. In a commercial feed processing plant, a producer can expect to pay approximately $40/ton of extruded ingredient, although the actual cost of processing can be as low as $20/ton, depending on location, electricity costs, labor, and depreciation. Using the $40/ton value, our diet costs were $115/ton for the control, $141/ton for the diet with extruded sorghum, $126/ton for the diet with extruded soybeans, and $153/ton for the diet with the extruded blend of sorghum and soybeans. Therefore, extrusion will increase diet costs, which will negate some of the economic benefits of increased litter weight gains for sows fed the extruded ingredients. Thus, the economic feasibility of extruding ingredients for lactation diets will depend on the case-by-case cost of extrusion and the value a producer places on increased litter weaning weights and reduced weight loss of sows during lactation.

Table 1. Diet Composition[a]

Item, %	Sorg-SBM	Extruded Sorghum	Extruded Soybeans	Extruded Sorg-SBM Blend
Sorghum	73.21	--	66.67	--
Extruded sorghum[b]	--	73.21	--	66.67
Soybean meal (48% CP)	20.24	20.24	--	--
Extruded soybeans	--	--	28.74	28.74
Soybean oil	1.96	1.96	--	--
Monocalcium phosphate (21% P)	2.23	2.23	2.23	2.23
Limestone	.96	.96	.96	.96
Salt	.50	.50	.50	.50
Trace mineral premix[c]	.15	.15	.15	.15
Sow add pack[c]	.25	.25	.25	.25
Vitamin premix[c]	.25	.25	.25	.25
Chromic oxide	.25	.25	.25	.25
Total	100.00	100.00	100.00	100.00

[a] All diets were formulated to .80% lysine, .90% Ca, .80% P, and 1.47 Mcal ME/lb of diet.
[b] Extruded sorghum replaced ground sorghum on an equal weight basis.
[c] KSU vitamin and mineral premixes.

Table 2. Effect of Extruded Sorghum and Soybeans on Sow Performance[a]

	Extrusion Treatment				
Item	Sorg-SBM[b]	Extruded Sorghum	Extruded Soybeans	Extruded Sorg-SBM Blend	CV
Sow wt postfarrowing, lb	387.3	371.5	389.4	387.0	--
Sow wt d 21, lb[efh]	370.3	341.8	374.8	374.4	5.7
Lactation wt loss, lb[gh]	17.0	29.7	14.6	12.6	99.5
Fat depth postfarrowing, in	.90	.90	.92	.95	--
Fat depth d 21, in[d]	.86	.88	.91	.92	13.1
Lactation fat loss, in	.04	.02	.01	.03	273.7
ADFI, lb[ci]	12.6	9.9	11.6	10.9	23.0

[a] A total of 117 primiparous sows (31 to 34 sows/treatment).
[b] SBM = soybean meal.
[cde] Sorghum-SBM vs extruded ingredients (P<.01, P<.10, P<.15, respectively).
[fg] Extruded blend vs extruded sorghum or soybeans (P<.01, P<.05, respectively).
[hi] Extruded sorghum vs extruded soybeans (P<.001, P<.05, respectively)

Table 3. Effect of Extruded Sorghum and Soybeans on Litter Performance[a]

	Extrusion Treatment				
Item	Sorg -SBM[b]	Extruded Sorghum	Extruded Soybeans	Extruded Sorg-SBM Blend	CV
Initial litter size	9.6	10.1	9.5	9.5	13.9
Pigs weaned[c]	8.9	9.2	9.3	9.0	9.7
Survivability, %[d]	91.4	94.4	95.0	93.0	8.4
Initial litter wt, lb	27.2	27.9	27.9	27.0	14.7
Final litter wt, lb[c]	96.4	101.4	101.6	102.8	14.3
Litter wt gain, lb[c]	69.2	73.5	73.7	75.8	16.9

[a] A total of 117 primiparous sows (31 to 34 sows/treatment).
[b] SBM = soybean meal.
[cd] Control vs extruded ingredients (P<.10, P<.15, respectively).

THE EFFECTS OF BMD IN LACTATION DIETS ON SOW AND LITTER PERFORMANCE[1]

B. T. Richert, J. L. Nelssen,
R. D. Goodband, and M. D. Tokach

Summary

One hundred forty-five multiparous sows were used in a performance trial to evaluate the use of BMD® (bacitracin methylene disalicylate) on sow and litter performance during lactation in a herd with no previously documented history of *Clostridium perfringens* type C or D. Between day 96 and 100 of gestation, sows were allotted to one of two dietary treatments, either a diet containing 250 g/ton of BMD or the control diet with no antibiotic. Sows were fed the experimental diets until weaning (approx. 20 d). Litters were equalized to approximately 10 pigs per sow within 48 hrs postfarrowing. Piglets were transferred only within treatment. Piglets on sows fed the BMD treatment had a reduced incidence of diarrhea (P=.10); however, the antibiotic had no effect on sow or litter performance.

(Key Words: Bacitracin, Sow, Lactation, Performance.)

Introduction

The use of an effective antibiotic to control the costly diarrhea often seen in the farrowing house is of economic importance to many producers. The use of BMD in the lactation diet may reduce piglet diarrhea caused by clostridial enteritis. Therefore, BMD was evaluated for its potential role in reducing baby pig diarrhea and improving pig performance when fed during lactation.

Procedures

One hundred forty-five white composite sows from a high-producing Kansas farm with a minimal disease level and no documented history of *Clostridium perfringens* type C or D were utilized in this trial. On day 96 to 100 of gestation, sows were allotted to one of two dietary treatments, BMD (250 g/ton) or the control (no antibiotic). Treatments were fed for the remainder of gestation and through lactation. Sows that did not receive BMD for a minimum of 14 days prior to farrowing were removed from the data set. Litters were equalized to approximately 10 pigs per sow within 48 hrs postfarrowing. Piglets were cross-fostered within treatments only. Sows were weighed prefarrowing and at weaning (d 20). Litters were weighed at birth, after equalization, and at weaning. Litter performance also was calculated by using the Ohio State adjustment formula, adjusting litter weaning weights based on days of lactation.

Results and Discussion

Sow and litter performance was excellent for both the control group and BMD-treated sows. No differences occurred in sow and litter performance between treatments. Litter weaning weights were similar at 129.1 lb for the BMD-fed sows and 128.0 lb for the control sows. When litter weaning weights were adjusted by the Ohio State days of lactation factors, they were

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[1] Appreciation is expressed to A.L. Laboratories, Inc., One Executive Drive, PO Box 1399, Fort Lee, NJ for donating the BMD and providing partial financial support for this experiment.

131.9 and 132.7 for the BMD and control sows, respectively. One of the areas in which an antibiotic response might be expected is piglet survival rate. Piglet survival was not affected by treatment and was high for both treatments, 92.9% for the control sows and 92.2% for the BMD fed sows. However, incidence of diarrhea was reduced by the BMD treatment (P=.10) when measured as the number of pigs treated per litter.

The effect of feeding 250 g/ton BMD in the sow's diet for this herd was minimal for improving performance. However, in herds with a higher disease level, BMD may have more beneficial effects.

Table 1. Gestation and Lactation Diet Composition

Item, %	Gestation Diet[a]	Lactation Diet[b]
Sorghum	80.09	68.06
Soybean meal, (46.5%)	15.49	24.70
Soybean oil	–	3.00
Monocalcium phosphate	2.27	2.14
Limestone	1.00	.95
Salt	.50	.50
KSU Vitamin premix	.25	.25
KSU Trace mineral premix	.15	.10
KSU Sow vitamin add pack	.25	.25
Vitamin E premix	–	.05
BMD[c]	.21	.21
Total	100.00	100.00

[a] Gestation diet formulated to .65% lysine, .9% Ca, .8% P.

[b] Lactation diets formulated to .90% lysine, .9% Ca, and .8% P.

[c] BMD 60 (bacitracin methylene disalicylate) included at 250 g/ton. BMD 60 replaced .21% of sorghum to create the BMD treated diets.

Table 2. Effect of Feeding BMD during Lactation on Sow and Litter Performance[a]

	Treatment		
Item	BMD	Control	CV
Number of sows per treatment	68	77	–
Standardized pigs born alive/litter[b]	9.90	9.90	11.44
Pigs weaned/litter	9.07	9.13	12.57
Piglet avg birth wt, lb	3.89	3.33	81.32
Piglet avg weaning wt, lb	14.20	14.00	12.11
Piglet ADG, lb	.505	.534	32.00
Percent survival, %[c]	92.16	92.89	11.87
Litter weaning wt, lb	129.1	128.0	18.75
Sow ADFI d 0 to 7, lb	13.90	14.14	12.46
Sow ADFI d 7 to 14, lb	16.55	16.22	12.66
Sow ADFI d 14 to weaning, lb	17.07	16.93	13.68
Sow ADFI d 0 to weaning, lb	15.84	15.76	10.25
Sow wt change during lactation, lb[d]	+19.22	+20.03	119.02
Incidence of diarrhea, pigs treated/litter[e]	.074	.169	281.30
Ohio State adjusted values[f]			
Piglet ADG, lb	.505	.530	30.76
Piglet avg weaning wt, lb	14.50	14.46	11.70
Litter weaning weight, lb	131.86	132.67	18.52

[a] Average length of lactation = 20.2 days.
[b] Standardized pigs born alive = pigs born alive + pigs transferred on - pigs transferred off.
[c] Percent survival = (pigs weaned/standardized pigs born alive) × 100.
[d] Sow weight change = sow prefarrowing weight - sow weaning weight.
[e] (P=.10).
[f] Ohio State adjusted values based on days of lactation.

GROWTH AND MICROBIOLOGY OF NONMEDICATED, SEGREGATED, EARLY-WEANED PIGS[1]

S. S. Dritz, M. M. Chengappa[2], J. L. Nelssen,
M. D. Tokach, R. D. Goodband, and M. W. Vorhies[3]

Summary

Seventy pigs, 7 to 10 d of age, were randomly selected by litter of origin from a commercial farm in Northeast Kansas to compare the growth and microbiology of nonmedicated, segregated, early-weaned pigs to controls raised at the farm of origin. After weaning, both groups were fed a similar nutritional programs consisting of dry diets. No antimicrobial drugs were administered to the pigs except for a feed grade antimicrobial (carbadox) from weaning to 50 lb. Pigs were monitored for 12 weeks. Individual pigs weights, nasal swabs, and serum samples were collected on d 0 and then every 14 d thereafter for a total of 7 collections. Four pigs were necropsied at the initiation of the study (d 0). In addition, four pigs were randomly selected at each collection period from each group for necropsy and collection of tissues for bacterial culture. The segregated early-weaned pigs were able to reach an accelerated phase of growth before the controls. On d 14, 28, 42, 56, and 70 of the experiment, segregated early-weaned pigs were 21, 82, 90, 54, and 52% heavier than control pigs, respectively. A low percentage of pigs were infected with *Pasteurella multocida* at 7 to 10 d of age, which corresponds to d 0 of the experiment. The principal time of transmission of *P. multocida* infection was in the immediate post-weaning period. The rate of isolation of *P. multocida* then declined from d 14 to d 84 of the experiment in both groups of non-medicated pigs. This response must be kept in mind when evaluating the efficacy of antibiotic protocols. Appropriate non-medicated controls must also be evaluated. The maximum difference in rate of isolation of *P. multocida* from nasal swabs and tissues between the early and control groups occurred on d 28 and d 42 of the experiment. This corresponds to the two collection days when segregated early-weaned pigs were 82% and 90% heavier than control pigs raised on-site. The only *Pasteurella multocida* isolates capable of producing toxin were detected on d 14 in the control group. *Pasteurella multocida* toxin has also been shown to have deleterious effects on systemic organs and immune response. The rates of *Bordetella bronchiseptica* isolation were similar between control and segregated early-weaned groups. However, *B. bronchiseptica* isolates were recovered from any tissues of any pigs necropsied. Antibiotic regimens targeted at this organism would appear unwarranted in a commercial production setting. *Haemophilus parasuis* and *Streptococcus suis* were present in both groups of pigs at 7 to 10 d of age. However, as indicated by the excellent growth performance achieved in the presence of *H. parasuis* colonization of the nasal cavity, elimination of this organism probably is not necessary to achieve excellent growth

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[1] Appreciation is expressed to Jacque Staats, Barb Kelly, John Kramer, and the employees of J-Six Farms for technical assistance.

[2] Department of Pathology and Microbiology.

[3] Department of Veterinary Diagnostic Investigations.

levels. More studies need to be undertaken to understand the mode of transmission and epidemiology of *Streptococcus suis* infection. *Mycoplasma hyopneumoniae* apparently was eliminated without medication by moving pigs to an isolated site. *Mycoplasma hyopneumoniae* could be detected only in the control group. Data from this experiment also suggest that weaning pigs at 14 to 17 d could prevent vertical transmission of *Actinobacillus pleuropneumonia*. The growth and microbiology of nonmedicated, segregated, early-weaned pigs must be considered when developing cost-effective and efficacious medication protocols for application of segregated early weaning in the commercial swine industry.

(Key Words: Pigs, Growth, Microbiology.)

Introduction

Early weaning in disease elimination procedures is becoming a common practice in the commercial swine industry. These procedures have evolved from research conducted in the 1950's on the elimination of enzootic pneumonia. Modifications of these procedures were reported in the 1980's. They consisted of farrowing the sows in isolation and medicating them prefarrowing and during lactation. Piglets were also medicated preweaning and postweaning. This procedure has become known as medicated early weaning. The original program was successful for disease elimination but increased levels of postweaning mortality (approximately 13%) occurred and were attributed to postweaning scour. Nutritional programs for the young pig now include highly palatable and highly digestible ingredients, which have greatly decreased the incidence of postweaning diarrhea. Medicated early-weaning has been further modified for application of early-weaning disease elimination on a commercial scale. The procedures have become known as modified, medicated, early weaning; isowean^{R}; or multiple-site production. However, these procedures typically employ the use of antibiotics administered to the sow and off-spring. Decreasing medication costs to a minimum will be necessary for the large-scale implementation of early-weaning, disease elimination procedures. Thus, our objective was to evaluate the growth and microbiology of nonmedicated, segregated, early-weaned pigs. Further understanding of growth and microbiology will aid in the development of cost-effective management procedures.

Procedures

Seventy pigs, 7 to 10 d of age, were randomly selected by litter of origin from a commercial farm in northeast Kansas. Thirty-two pigs were early-weaned at 7 to 10 d of age and transported to isolation nurseries at the Kansas State University College of Veterinary Medicine for the duration of the 84 d experiment. Thirty-four litter mates were weaned conventionally on-site at 14 to 17 d of age. They served as the control group. Four pigs were necropsied at the initiation of the study on d 0. All facilities were environmentally controlled, and pigs had ad libitum access to feed and water after weaning. After weaning, both groups were fed a similar nutritional programs consisting of dry diets. No antimicrobial drugs were administered to the pigs except for a feed grade antimicrobial (carbadox) from weaning to 50 lb. The farm was known to be infected with *Mycoplasma hyopneumoniae*, *Bordetella bronchiseptica*, toxigenic *Pasteurella multocida*, *Haemophilus parasuis*, *Streptococcus suis*, and *Actinobacillus pleuropneumonia*. Sows and gilts received no parenteral or feed-grade antibiotics prefarrowing or during lactation.

Pigs were monitored for 12 weeks. Individual pig weights, nasal swabs, and serum samples were collected on d 0 and then every 14 d thereafter for a total of 7 collections. The first collection for both groups was at the time of weaning for the segregated early-weaned group (d 0). In addition, four pigs were randomly selected at each collection period from each group for necropsy and collection of tissues for bacterial culture. Tissues cultured from the eight pigs were: tonsil, lung, liver, spleen, brain, meningeal swabs, intestine, and mesenteric lymph node.

Nasal swabs and tissue specimens were cultured aerobically for bacteria. Because virtually all samples contained a large number of *Streptococcus* spp. per nasal sample, 10% of colonies were randomly selected and biochemically characterized to species. *Pasteurella multocida* and *Bordetella bronchiseptica* were assayed for the production of dermal necrotic toxin. All pigs necropsied were examined for the presence *Mycoplasma hyopneumoniae* using a fluorescent antibody technique. Lung tissue from all pigs negative by fluorescent antibody testing was cultured for the presence of *M. hyopneumoniae*. Serum from all pigs was evaluated for the presence of antibodies to *M. hyopneumoniae* and *Actinobacillus pleuropneumonia*.

Results and Discussion

Growth Performance. The segregated early-weaned pigs were able to reach the accelerated phase of the growth curve before the controls (Figure 1). On d 14, 28, 42, 56, and 70 of the experiment, segregated early-weaned pigs were 21, 82, 90, 54, and 52% heavier than control pigs, respectively. The growth curve of animals is sigmoidal in shape and can be divided into four phases: lag, accelerated, linear, and maturity. Accelerated growth occurs when the rate of increased growth is non-linear. Part of the advantage of early weaning may be due to segregated early-weaned pigs reaching the accelerated growth phase sooner than control pigs. These growth data illustrate that pigs have a tremendous biologic potential for growth that is not being realized in many commercial production systems.

Bacteriology Culture Studies. A low percentage of pigs was infected with *Pasteurella multocida* at 7 to 10 d of age (Table 1). This would be advantageous for developing a medication regimen for the elimination of this organism. The principal time of transmission of *P. multocida* infection is the immediate postweaning period. This is indicated by the rate of nasal swab isolation rising from 6% to 22% in the segregated early-weaned pigs and from 0% to 50% in the control group. Day 14 of the experiment was d 14 postweaning for the segregated early-weaned group and d 7 postweaning for the farm-raised controls. The increased rate of transmission postweaning could be explained by three factors: 1) increase in pig density postweaning, 2) decreased immune response capability immediately postweaning, and 3) commingling of piglets during transport to the nursery. The rate of isolation of *P. multocida* declined from d 14 to d 84 of the experiment in both groups of nonmedicated pigs. This response must be kept in mind when evaluating the efficacy of antibiotic protocols. Appropriate nonmedicated controls also must be evaluated. The cost to benefit ratio of antibiotics for the elimination of *P. multocida* needs to be evaluated further.

The maximum difference in rate of isolation of *P. multocida* from nasal swabs and tissues between the early and control groups occurred on d 28 and d 42 of the experiment. This corresponds to the two collection days when segregated early-weaned pigs were 82% and 90% heavier than control pigs raised on-site. Research in poultry suggests that stimulation of the immune system in growing chicks causes decreased feed intake and nutrient utilization. The immune stimulation is thought to occur by exposure of the immune system of nonpathogenic organisms from the animal's environment. Because *P. multocida* was the only microorganism consistently isolated from systemic organs, this bacterium may play a key role as a cause of continual nonpathogenic stimulation of the immune system. The only *Pasteurella multocida* isolates capable of producing toxin were detected on d 14 in the control group. *P. multocida* toxin also has been shown to have deleterious effects on systemic organs and immune response. Isolation of the toxigenic strains from the d 14 collection corresponds to when the segregated early-weaned pigs were 82% heavier than the control pigs. Toxin production may be a key influence on the growth of pigs in the nursery period.

Isolation of *Bordetella bronchiseptica* increased in the d 56, 70, and 84 nasal swab samples in both the early-weaned and control pigs (Table 2). No *B. bronchiseptica* isolates were recovered from any tissues of any pigs necropsied. The rates of *B. bronchiseptica* isolation were similar between control and segregated early-weaned groups. *Bordetella bronchiseptica* organisms were not isolated until d 56 of the experiment. These results would indicate that off-spring receive adequate maternal immunity until they develop an innate resistance to this organism. With little colonization by *B. bronchiseptica*, very few toxigenic *P. multocida* organisms were able to colonize. Thus, the organisms were subsequently eliminated from the nasal passage. This could explain why no toxigenic *P. multocida* organisms were detected after the d 14 collection and few clinical signs of rhinitis were present. *Bordetella bronchiseptica* infection does not seem to cause systemic infection or have a negative influence on growth performance when pigs are infected at this age. Therefore, elimination of this organism would have little impact on growth performance. Current control strategies should concentrate on stimulation and transfer of maternal immunity. Antibiotic regimens targeted at this organism would appear unwarranted in a commercial production setting.

Haemophilus parasuis was isolated from 78% and 47% of the early-weaned and control pigs, respectively, on d 0 (Table 3). The rates decreased to 31% and 9%, respectively, on d 14 of the experiment and then rose to 80% and 74% for the early-weaned and control pigs on d 56 of the experiment. No *H. parasuis* isolates were recovered from any tissues of any pigs necropsied. The high rate of *H. parasuis* isolation from the nasal passage indicates that maternal transfer of immunity had little affect on the colonization of this organism. It is well known that *H. parasuis* can cause mortality in an immunologically naive herd. The absence of clinical disease in the presence of infection of very young pigs indicates that these pigs had transfer of maternal immunity. However, as indicated by the excellent growth performance achieved in the presence of *H. parasuis* colonization of the nasal cavity, elimination of this organism probably is not necessary. Because this organism can cause severe disease in immunologically naive populations, elimination of this organism may be desirable.

Streptococcus suis was present in many of the isolates from 7- to 10-d-old of age pigs. Several serotypes were isolated with no consistent pattern. No clinical signs of systemic *S. suis* infection were noted in the segregated early-weaned or control pigs. The data from this experiment indicate that *S. suis* is present in a large percentage of 7- to 10-d-old pigs. More studies need to be undertaken to understand the mode of transmission and epidemiology of *S. suis* infection.

***Mycoplasma hyopneumoniae* Culture and Serology**. *Mycoplasma hyopneumoniae* apparently was eliminated without medication by moving pigs to an isolated site. *Mycoplasma hyopneumoniae* could be detected only in the control group. One pig from each control necropsy group in the d 42, 70, and 84 collections was positive for the presence of *M. hyopneumoniae* by fluorescent antibody testing; however, all pigs in the early group were negative for its presence by the same procedure. *Mycoplasma hyopneumoniae* was not detected in any of the samples cultured. Further indication of *M. hyopneumoniae* elimination is provided by the serologic results (Table 4). On d 14 one pig had a titer to *Mycoplasma hyopneumoniae* greater than 0.2; however, the titer from this pig had decreased to less than 0.2 on d 28. Three pigs on d 28 had titers greater than 0.2. These three titers were all higher than on the previous collection at d 14. The serologic results indicate that a small proportion of pigs in the control group were sero-converting and show a slow spread of infection.

***Actinobacillus pleuropneumonia* Serology**. No pigs had rising titers for the duration of the experiment. This indicates that neither sero conversion nor transmission of infection was taking place. The proportion of titers greater than 6000 decreased from d 0 to 42 at the same rate in both groups (Table 5). No samples were detected from d 42 to the end of the experiment, with titers greater than 6000. High levels of antibody specific for *A. pleuropneumonia* were detected in both groups of pigs on d 0. One hundred percent of pigs in both groups had titers greater than 6000. Serology results suggest very good maternal transfer of antibody to *A. pleuropneumonia*. These data suggest that, in the presence of high maternal immunity, weaning pigs at 14 to 17 d could prevent vertical transmission of *A. pleuropneumonia*.

In conclusion, the pig's potential for growth is not being achieved in many present production systems. Possible explanations for the growth response in early-weaning programs are: 1) segregated early-weaned pigs reaching the accelerated growth phase sooner, 2) absence of deleterious effects of pathogenic microorganism infection, or 3) decreased feed intake and altered nutrient partitioning because of nonpathogenic stimulation of the immune system. The growth and microbiology of nonmedicated, segregated, early-weaned pigs must be considered when developing cost-effective and efficacious medication protocols for application of segregated early weaning in the commercial swine industry.

Table 1. Recovery of *Pasteurella multocida* from Nasal Swab and Tissue Specimens

	Day						
Sample	0	14	28	42	56	70	84
Nasal Swabs							
Early-Weaned							
Type A	-	3	1	1	-	-	-
Type D	-	3	-	-	-	1	-
Nontypeable	2	1	-	-	-	-	-
Total	6% (2/32)[a]	22% (7/32)	4% (1/28)	4% (1/24)	0% (0/20)	6% (1/16)	0% (0/12)
Control							
Type A	-	2	12	11	4	3	2
Type D	-	14[b]	2	-	-	-	1
Nontypeable	-	1	-	-	-	-	-
Total	0% (0/28)	50% (17/34)	47% (14/30)	42% (11/26)	21% (4/19)	19% (3/16)	23% (3/13)
Necropsy Tissues[c]							
Early-Weaned							
Type A	NA[d]	-	1	1	2	1	-
Type D	NA	-	-	1	-	-	-
Nontypeable	NA	1	-	-	-	-	-
Total	NA	1	1	2	2	1	-
Control							
Type A	NA	1	1	3	4	4	4
Type D	NA	3	3	1	1	-	-
Nontypeable	NA	1	2	-	-	-	-
Total	NA	5	6	4	5	4	4

[a] Percentage (number nasal swabs positive / total number of nasal swabs).

[b] Three isolates positive for the production of toxin.

[c] Each number represents the total number of positive tissues for the total of four pigs. Tissues cultured were: tonsil, lung, liver, spleen, brain, and meningeal swab.

[d] No *Pasteurella multocida* were isolated from the four pigs necropsied on d 0.

Table 2. Recovery of *Bordetella bronchiseptica* from Nasal Swabs

	Day						
Group	0	14	28	42	56	70	84
Early-Weaned	0% (0/32)[a]	0% (0/32)	0% (0/28)	0% (0/24)	25% (5/20)	38% (5/16)	25% (3/12)
Control	0% (0/28)	0% (0/34)	10% (3/30)	0% (0/26)	11% (2/19)	31% (6/16)	54% (7/13)

[a] Percentage (number nasal swabs positive / total number of nasal swabs).

Table 3. Recovery of *Haemophilus parasuis* from Nasal Swabs[a]

	Day						
Group	0	14	28	42	56	70	84
Early-Weaned	78% (25/32)[b]	31% (10/32)	64% (18/28)	75% (18/24)	80% (16/20)	56% (9/16)	50% (6/12)
Control	47% (16/28)	9% (3/34)	30% (9/30)	42% (11/26)	74% (16/19)	31% (5/16)	46% (6/13)

[a] No Haemophilus parasuis were found in any necropsy tissues.
[b] Percentage (number nasal swabs positive / total number of nasal swabs).

Table 4. Serology Results for *Mycoplasma hyopneumoniae*

	Week						
Group	0	2	4	6	8	10	12
Early-Weaned	26%[a] (7/34)[b]	6% (2/31)	4% (1/28)	0% (0/23)	0% (0/18)	0% (0/16)	0% (0/9)
Control	26% (9/34)	3% (1/34)	11% (3/27)	8% (2/25)	5% (1/19)	7% (1/15)	7% (7/14)

[a] Percentage of samples with an absorbance > 0.2.
[b] (number of samples > 0.2 / total number of samples).

Table 5. Serology Results for *Actinobacillus pleuropneumonia*

	Week						
Group	0	2	4	6	8	10	12
Early-Weaned	100% (30/32)[a]	94%[a] (30/32)	46% (13/28)	0% (0/24)	0% (0/18)	0% (0/16)	0% (0/11)
Control	100% (34/34)	91% (31/34)	61% (14/26)	0% (0/25)	0% (0/17)	0% (0/16)	0% (0/15)

[a] Percentage (number of serum samples >6000 / total number of serum samples).

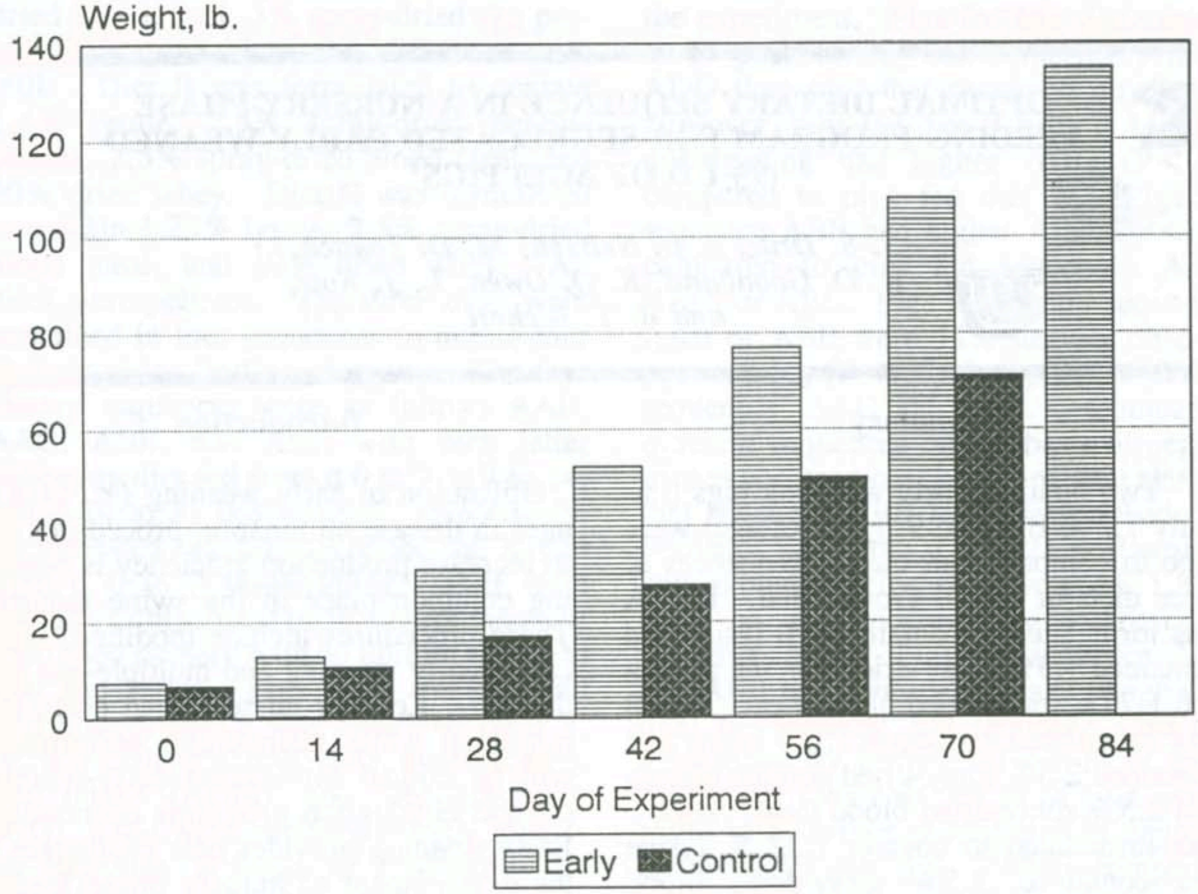

Figure 1. **Weights of Segregated Early-Weaned Pigs and Farm Raised Controls**

Site Preparation of the New KSU Segregated, Early-Weaning Facility.

INFLUENCE OF INTERLEUKIN-1 ON NEUTROPHIL FUNCTION AND RESISTANCE TO *STREPTOCOCCUS SUIS* IN YOUNG PIGS

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Summary

Nonspecific immunity is usually lower in young pigs than adults. Consequently, enhancing the young pig's nonspecific immune capability may be beneficial for the health and performance of early-weaned pigs. Twenty, 9-d-old, crossbred pigs were allotted by litter and weight into two treatment groups: recombinant bovine interleukin-1β (rBoIL-1β; 5 µg/kg, intramuscularly at 9 and 10 d of age)) or control. Pigs were weaned at 10 d of age and housed in an isolation facility with ad libitum access to water and a pelleted diet formulated to meet the nutrient requirements and provide maximum growth of early-weaned pigs. Blood samples were obtained on 9, 12, 15, and 18 d of age for determination of several neutrophil function assays including: bactericidal activity, antibody-dependent cellular cytotoxicity (ADCC), and superoxide anion production. Pigs were challenged with *S. suis* (serotype 2) at 18 d of age. Neutrophil-mediated ADCC was increased at 12, 15, and 18 d of age in pigs treated with rBoIL-1β. Two days postweaning, neutrophil-mediated lysis of *Staphylococcus aureus* was lower in control pigs when compared to rBoIL-1β-treated pigs (6.6 vs 13.3%). Superoxide anion production was not influenced by rBoIL-1β treatment. Clinical signs of *S. suis* infection were less severe in pigs administered rBoIL-1β. These data suggest that rBoIL-1β increases neutrophil function and resistance to *S. suis* in early-weaned pigs.

(Key Words: Early Weaning, Immunity, Immune Enhancement.)

Introduction

Newborn animals lack a fully competent immune system. This situation is particularly relevant in pigs for several reasons. For example, it has been repeatedly shown that young pigs have low or absent nonspecific immune responses. This finding is usually illustrated by low or absent natural killer cell activity in neonatal pigs until approximately 2 to 3 weeks of age. Additionally, neutrophil functions have been shown to be lower in neonatal pigs when compared to adult values. These observations suggest that enhancing the young pig's nonspecific immune capability may be beneficial and may allow early weaning without the extensive reliance on mass medication of the newborn.

One approach to immune enhancement is the use of cytokines. Interleukin-1 (IL-1) and interleukin-2 (IL-2) have been shown to have specific and nonspecific immuno-

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We thank American Cyanamid Co., Princeton, NJ for providing the interleukin-1 and Steve Eichman for his help with the project.

modulating functions in immunosuppressed or neonatal animals, and enhancement of nonspecific antibacterial resistance by IL-1 is well documented. Porcine IL-1α, IL-1β, and IL-2 have been cloned and expressed, but are not available in sufficient quantities for in vivo experiments. However, porcine IL-1β and bovine IL-1β have a high degree of similarity, and recombinant bovine IL-1β (rBoIL-1β) is biologically active in pigs. Therefore, the purpose of this study was to investigate the influence of rBoIL-1β on nonspecific immunity and disease resistance in young pigs.

Procedures

Twenty, 9-d-old, crossbred pigs from three litters were allotted by litter and weight into two groups: rBoIL-1β (5 µg/kg, intramuscularly, at 9 and 10 d of age) or control (equal volume of physiologic saline, intramuscularly). Pigs were weaned at 10 d of age and housed in an isolation facility in polyethylene pens (Poly Dome Pig Nursery, Litchfield, MN). Pigs had ad libitum access to water (nipple waterers) and a pelleted diet formulated to meet the nutrient requirements and provide maximum growth of early-weaned pigs. Blood samples were obtained on 9, 12, 15, and 18 d of age for determination of neutrophil bactericidal activity, antibody-dependent cellular cytotoxicity (ADCC), and superoxide anion production. Pigs were inoculated intravenously with *Streptococcus suis*, serotype 2, (3×10^9 CFU) at 18 d of age, and clinical signs were monitored and recorded daily for 7 d.

Results and Discussion

Two days after weaning, the capability of neutrophils to lyse *S. aureus* was lower ($P<.05$) in control pigs (6.6%±2.1) than in rBoIL-1β-treated pigs (13.0%±2.0). This finding suggests that IL-1 treatment prevented a weaning-induced decrease in neutrophil bactericidal activity. Although neutrophil production of superoxide anion did not differ between the two groups, neutrophil-mediated antibody-dependent cellular cytotoxicity was increased ($P<.05$) after rBoIL-1β administration. When pigs were challenged with *S. suis*, rBoIL-1β-treated pigs had a significantly lower severity of disease than the saline-injected controls (Fig. 1).

Interleukin-1 is a predominantly macrophage or monocyte-derived protein that modulates many of the responses involved in the process of host defense to infection, including neutrophil functions, such as adherence, cell migration, respiratory burst, lysosomal enzyme release, and cell surface receptor expression. Our data suggest that rBoIL-1β may selectively enhance neutrophil antimicrobial activity and increase resistance to streptococcal infection in neonatal pigs. Thus, age- or early-weaning-associated immune defects in young pigs may be improved by administration of interleukin-1.

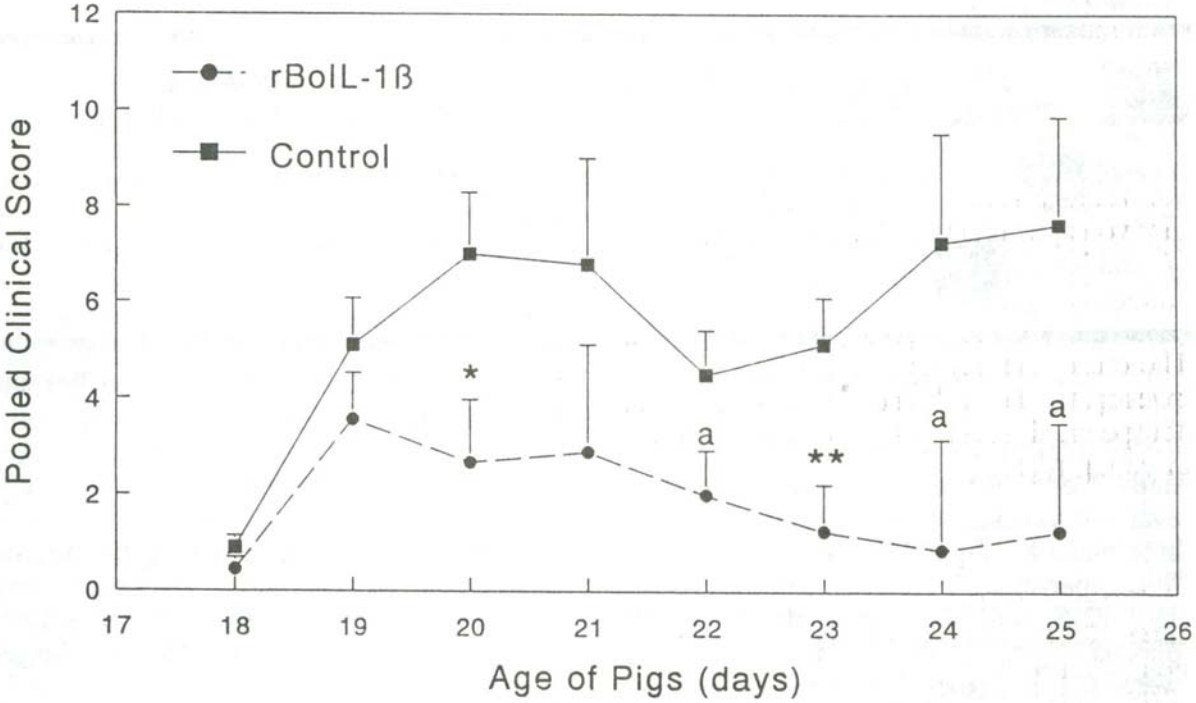

Figure 1. **Pooled Clinical Signs after *S. suis* Challenge in Pigs Treated with rBoIL-1β or Saline (Control). Pigs were weaned at 10 d of age, injected intramuscularly with rBoIL-1β (5 µg/kg at 9 and 10 d of age) or physiologic saline, and inoculated intravenously with *S. suis*, serotype 2, (3×10^9 CFU) on d 18. Clinical score increases in severity of disease from 0 to 10 and includes dyspnea, lameness, depression, CNS signs, and rectal temperature. Values are means ± SEM, n=10, ^{a}P<.07, *P<.05, **P<.01**

OPTIMAL DIETARY SEQUENCE IN A NURSERY-PHASE FEEDING PROGRAM FOR SEGREGATED EARLY-WEANED (9±1 D OF AGE) PIGS[1]

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R. D. Goodband, K. Q. Owen, L. J. Kats,
and B. T. Richert

Summary

Two hundred forty weanling pigs (initially 7.2 lb BW and 9 ± 1 d of age) were used to compare four dietary sequences of three diets in a 21-d growth trial. Diet A was formulated to contain 1.7% lysine and contained 7.5% spray-dried porcine plasma and 1.75% spray-dried blood meal. Diet B was formulated to contain 1.4% lysine and contained 2.5% spray-dried porcine plasma and 2.5% spray-dried blood meal. Diet C was formulated to contain 1.25 % lysine and contained 2.5% spray-dried blood meal. The four dietary sequences were as follows AAB, AAC, ABB, and ABC, with each letter indicating the diet fed from d 0 to 7, d 7 to 14, and d 14 to 21 postweaning, respectively. Pigs fed diet B from d 7 to 14 postweaning had numerically lower average daily gain (ADG) than pigs remaining on diet A. However, pigs fed diet B from d 14 to 21 postweaning had higher ADG compared to pigs fed diet C. Pigs fed dietary sequences AAB or ABB were 11% heavier on d 21 postweaning than pigs fed dietary sequences AAC or ABC. In conclusion, dietary sequences AAB and ABB provided identical performance from d 0 to 21 postweaning; however, utilization of a transition diet (B) from d 7 to 14 postweaning substantially reduced feed cost per lb of gain for pigs weaned at 9 d of age.

(Key Words: Starter, Performance, Diet Sequence.)

Introduction

Utilization of early weaning (< 14 d of age) in disease elimination procedures and to increase production efficiency is becoming common place in the swine industry. These procedures include modified, medicated, early weaning and multiple-site production. Keeping nursery feed costs to a minimum while maintaining performance will be critical for making early-weaning disease elimination programs economical. Early weaning provides new challenges in the development of nursery phase feeding programs to minimize feed cost and maximize performance. Thus, our objective was to develop an optimal dietary sequence for early weaned pigs. The objective was accomplished by feeding four dietary sequences of three diets in a nursery-phase feeding program.

Procedures

Two hundred forty weanling pigs (initially 7.2 lb BW and 9 ± 1 d of age) were used in a 21-d growth trial to evaluate the influence of four dietary sequences on growth performance. The experiment was designed as a split plot with five replicates per dietary sequence. The whole plot was dietary sequence, and the subplot was time period. Pigs were blocked by weight. Three diets (Table 1) were used to form the four dietary sequences. Diet A was formulated to contain 1.7% lysine, 7.5% spray-dried porcine plasma, 1.75% spray-dried

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[1] Appreciation is expressed to John Kramer and the employees of J-Six Farms for assistance and for use of facilities and animals in this experiment.

blood meal, 3% spray-dried egg protein, 20% dried whey, and 10% dried skim milk. Diet B was formulated to contain 1.4% lysine, 2.5% spray-dried porcine plasma, 2.5% spray-dried blood meal, and 20% dried whey. Diet C was formulated to contain 1.25% lysine, 2.5% spray-dried blood meal, and 10% dried whey. All diets were pelleted. The three diets were combined in four sequences to mimic four nursery-phase feeding programs. The four dietary sequences were as follows AAB, AAC, ABB, and ABC with each letter indicating diet fed from d 0 to 7, d 7 to 14, and d 14 to 21 postweaning, respectively. As indicated, all pigs were fed the A diet from d 0 to 7 postweaning. Pigs were housed (12 pigs/pen) in an environmentally controlled nursery with ad libitum access to feed and water. Pigs were weighed and feed disappearance was measured on d 7, 14, and 21 to evaluate ADG, average daily feed intake (ADFI), and feed efficiency (F/G). Data were analyzed using a repeated measures analysis of variance. A Satterthwaite degree of freedom correction was utilized to make the comparison across dietary sequence for each time period.

Results and Discussion

From d 0 to 7 postweaning, pigs fed the common diet A gained .25 lb/d, consumed .30 lb/d, and had a feed efficiency of 1.20. No differences occurred in performance for this time period. No differences were seen in feed efficiency between dietary sequences for any time period of the experiment. Pigs fed Diet B from d 7 to 14 postweaning had numerically lower ADG than pigs that remained on diet A. However, pigs fed diet B from d 14 to 21 postweaning had higher ADG (P<.05) compared to pigs fed diet C. Pigs fed sequence ABB had higher ADFI (P<.05) compared to pigs fed sequences AAB, AAC, or ABC. Pigs fed dietary sequences AAB or ABB were 11% heavier on d 21 postweaning (P<.05) than pigs fed dietary sequences AAC or ABC. Comparing different sequences on the basis of performance and feed cost per lb of gain showed that sequence ABB had a lower feed cost per lb of gain from d 0 to 21 postweaning and produced pigs that weighed 1.3 lb more on d 21 postweaning compared to sequence AAC. Pigs fed sequence AAB and ABB had identical average weights on d 21 postweaning, but sequence ABB had a substantially lower cost per lb of gain. The lower feed cost per lb of gain would result in a savings in feed cost of approximately $.58 per pig. When comparing sequence ABC to ABB, pigs receiving sequence ABB were 1.3 lb heavier on d 21 postweaning. However, pigs receiving sequence ABC had a lower feed cost per lb of gain. This trial illustrates the large impact nursery phase feeding programs have on feed cost per lb of gain. In conclusion, dietary sequences AAB and ABB provided identical performance from d 0 to 21 postweaning; however, utilization of a transition diet (B) from d 7 to 14 postweaning substantially reduced feed cost per lb of gain for pigs weaned at 9 d of age.

Table 1. Diet Composition[a]

	Diet		
Item, %	A	B	C
Corn	41.05	45.60	58.29
Soybean meal, (48% CP)	7.90	20.27	21.90
Dried whey, edible grade	20.00	20.00	10.00
Dried skim milk	10.00	--	--
Spray-dried porcine plasma	7.50	2.50	--
Spray-dried egg protein	3.00	--	--
Spray-dried blood meal	1.75	2.50	2.50
Soybean oil	5.00	5.00	3.00
Monocalcium phosphate	1.67	1.80	1.96
Limestone	.55	.70	.82
Antibiotic[b]	1.00	1.00	1.00
Trace mineral premix	.15	.15	.15
Vitamin premix	.25	.25	.25
DL-methionine	--	.05	.05
L-lysine HCl	.10	.10	.15
Copper sulfate	.075	.075	.075
Total	100	100	100

[a] Diets were formulated to contain 1.7% lysine (Diet A), 1.4% lysine (Diet B), or 1.25% lysine (Diet C) and .9% Ca and .8% phosphorus.
[b] Provided 50 g/ton carbadox.

Table 2. Growth Performance of Pigs Fed Four Dietary Sequences in a Nursery-Phase Feeding Program[a]

	Dietary Sequence				
Item	AAB	AAC	ABB	ABC	CV
d 7 to 14					
ADG, lb[b]	.61	.62	.56	.49	14.0
ADFI, lb	.66	.65	.66	.63	7.7
F/G	1.09	1.06	1.20	1.29	18.9
d 14 to 21					
ADG, lb[c]	.75	.59	.80	.64	14.0
ADFI, lb[d]	.82	.74	.96	.83	7.7
F/G	1.09	1.26	1.20	1.30	18.9
d 21					
Wt, lb[c]	18.5	17.2	18.5	17.2	9.4
d 0 to 21					
Cost/lb gain, $[e]	.332	.316	.280	.230	----

[a] Two hundred forty weanling pigs were used (initially 7.2 lb and 9 d of age), 12 pigs/pen, 5 pens per sequence.
[b] AAB or AAC vs ABC ($P<.05$).
[c] AAB or ABB vs AAC or ABC ($P<.05$).
[d] ABB vs AAB, AAC, or ABC ($P<.05$) ABC vs AAC ($P<.09$).
[e] Diet costs: A, $.40/lb; B, $.20/lb; C, $.10/lb.

OPTIMUM LEVEL OF SPRAY-DRIED PORCINE PLASMA FOR EARLY-WEANED (10.5 D OF AGE) STARTER PIGS[1]

S. S. Dritz, M. D. Tokach, R. D. Goodband,
J. L. Nelssen, and K. Q. Owen

Summary

A total of 290 early-weaned pigs (initially 7.6 lb and 10.5 d of age) was used to evaluate various levels of spray-dried porcine plasma. Pigs were assigned to one of five experimental diets with either 5, 7.5, 10, 12.5, or 15% spray-dried porcine plasma replacing dried skim milk. Pigs were fed this diet for the first 14 days postweaning. Common diets were fed from d 14 to 42 postweaning in order to monitor subsequent performance. During the first phase (d 0 to 14 postweaning), linear improvements in average daily gain (ADG) and average daily feed intake (ADFI) occurred as the level of spray-dried porcine plasma increased from 5% to 15%. This resulted in a linear improvement in weight at d 14 postweaning. For the first phase and subsequent phases, no differences occurred in feed efficiency (F/G). From d 14 to 21 postweaning, a linear decrease occurred in ADG and ADFI as well as a linear deterioration of F/G as the level of spray-dried porcine plasma increased from 5% to 15%. This reversal of performance resulted in no difference of pig weights at d 21 and 25 postweaning. From d 25 to 42 postweaning, no difference was seen in ADG. In summary, spray-dried porcine plasma can be used as an effective replacement for dried skim milk as a protein source in diets for pigs weaned at 10 d of age.

(Key Words: Starter, Spray-dried Porcine Plasma, Skim Milk.)

Introduction

Early weaning is becoming a common practice in the commercial swine industry as a part of disease elimination programs. Spray-dried porcine plasma has been largely responsible for the success of early weaning because of its stimulatory effects on feed intake. To date information is lacking in regard to the optimum level of spray-dried porcine plasma in diets for the very early-weaned pig. Recent research at Kansas State University has found a linear increase in ADG and ADFI when adding up to 10% spray-dried porcine plasma in the phase I diet of conventionally weaned (21 d of age) pigs. This response was obtained when the methionine:lysine ratio was maintained above the ratio suggested by NRC (1988). Additionally, further research at Kansas State University suggests that the methionine:lysine ratio for diets containing spray-dried blood products is higher than that suggested by NRC (1988). The objective of this experiment was to determine the optimum level of spray-dried porcine plasma for diets of early-weaned (10 d of age) pigs, while maintaining a methionine to lysine ratio of $\geq .275:1$.

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[1] Appreciation is expressed to American Proteins Corporation for partial funding and donation of spray-dried porcine plasma. The authors wish to thank Steve and Brent Eichman and Eichman Farms, St. George, KS for use of animals and facilities for this experiment.

Procedures

A total of 290 weanling pigs (initially 7.6 lb and 10.5 d of age) was used on a commercial operation in Kansas to evaluate various levels of spray-dried porcine plasma in the phase I (d 0 to 14 postweaning) diet. Pigs were blocked by weight to the five experimental treatments. Pigs were housed nine or 10 pigs per pen (six pens per treatment) in an environmentally controlled nursery with metal flooring and allowed ad libitum access to feed and water. Pigs and feeders were weighed on d 7, 14, 21, and 25 after weaning to determine ADG, ADFI, and F/G. On d 28 postweaning, pigs were moved to an environmentally controlled, slatted floor, grower facility. Pigs were weighed on d 42 postweaning to determine ADG.

Experimental diets were formulated to contain either 5, 7.5, 10, 12.5, or 15% spray-dried porcine plasma (Table 1). Spray-dried porcine plasma replaced dried skim milk on a lysine basis with soybean meal maintained at a constant level (11%) in all diets. Lactose was added to the diet as dried skim milk was removed to maintain a constant lactose level (30%) in all diets. All diets were formulated to contain 1.8% lysine, .52% methionine, .9% calcium, and .8% phosphorus (Table 1). Pigs were fed the experimental diets for the first 14 days postweaning. On d 14 postweaning, all pigs were switched to a common transition diet (d 14 to 25 postweaning) containing 20% dried whey, 2.5% spray-dried porcine plasma, and 2.5% spray-dried blood meal (Table 1). This diet was formulated to contain 1.4% lysine, .42% methionine, .9% calcium and .8% phosphorus. Both phases were fed in the pellet form. A 3/32-in diameter pellet was fed in the first phase. In the transition phase, a 5/32-in diameter pellet was fed. From d 25 to 32 postweaning, all pigs were fed a common phase II diet containing 2.5% spray-dried blood meal and 10% dried whey. All pigs were fed a common phase III corn-soybean meal diet from d 32 to 42 postweaning. This diet was formulated to contain 1.1% lysine.

Results and Discussion

Average daily gain improved linearly (P<.06) during the first phase, with pigs fed the 15% spray-dried porcine plasma having the greatest performance (Table 2). Average daily feed intake was also improved linearly (P < .01). The pigs receiving the 15% plasma diet consumed the most feed during the d 0 to 14 postweaning period (Table 2). Pig weight increased linearly (P < .06) on d 14 postweaning as the percentage of spray-dried porcine plasma increased in the diet. Pigs receiving the 15% spray-dried porcine plasma diet were .7 lb heavier than the pigs consuming the 5% spray-dried porcine plasma diet (Table 3). In the first 7 days of the transition phase (d 14 to 21 postweaning), a linear decrease occurred in ADG and ADFI (P < .01, .04 respectively) as the inclusion level of spray-dried porcine plasma increased from 5% to 15%. Feed efficiency (F/G) also deteriorated linearly (P < .04) as the percentage of spray-dried porcine plasma increased from 5% to 15% (Table 2). For the entire transition phase, no differences occurred in ADG, ADFI, and F/G. However, numeric decreases were seen in ADG and ADFI as the amount of spray-dried porcine plasma increased from 5% to 15%. This reversal in performance resulted in no differences in weight between treatments on d 25 postweaning. From d 25 to 42 postweaning, no difference occurred in ADG, resulting in no differences in weight on d 42 postweaning (Table 3). These results have been observed in previous experiments. They could be caused by an increased metabolic demand for nutrients not being met in the second phase by pigs performing very well in the first phase. In summary, spray-dried porcine plasma can be used as an effective replacement for dried skim milk as a protein source in diets for pigs weaned at 10 d of age.

Table 1. Diet Composition[a]

	Spray-dried Porcine Plasma, % - Phase I							
Item, %	5	7.5	10	12.5	15	Trans-ition	Phase II	Phase III
Corn	22.77	22.91	23.05	23.19	23.25	44.86	60.73	67.06
Soybean meal (48.5 % CP)	11.00	11.00	11.00	11.00	11.00	20.92	22.37	28.07
Dried whey, edible grade	25.00	25.00	25.00	25.00	25.00	20.00	10.00	--
Spray-dried porcine plasma	5.00	7.50	10.00	12.50	15.00	2.50	--	--
Dried skim milk	24.06	18.04	12.03	6.01	--	--	--	--
Soy oil	6.00	6.00	6.00	6.00	6.00	5.00	--	--
Lactose	--	3.00	6.00	9.00	12.00	--	--	--
Select menhaden fish meal	4.00	4.00	4.00	4.00	4.00	--	--	--
Spray-dried blood meal	--	--	--	--	--	2.50	2.50	--
Limestone	.015	.075	.134	.194	.253	.698	.843	.95
Antibiotic	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Monocalcium phosphate (21 %P)	.51	.79	1.06	1.34	1.61	1.79	1.91	2.05
Salt	--	--	--	--	--	--	--	.30
Vitamin premix	.25	.25	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15	.15	.15
Vitamin E premix	.05	.05	.05	.05	.05	--	--	--
Copper sulfate	.075	.075	.075	.075	.075	.075	.075	.075
L-lysine HCl	.075	.075	.075	.075	.075	.10	.10	.10
DL-methionine	--	.083	.124	.166	.207	.150	.075	--
Isoleucine	--	--	--	--	.081	--	--	--
Total	100	100	100	100	100	100	100	100

[a] Diets were formulated to contain 1.8% lysine, .53% methionine, .9% Ca, and .8% P in phase I and 1.4% lysine, .42% methionine, .9% Ca, and .8% P in the transition phase.

[b] Provided 150 g/ton apramycin in phase I and 50 g/ton carbadox in the transition phase.

Table 2. Effect of Spray-dried Porcine Plasma Level on Growth Performance of Pigs Weaned at 10.5 d of Age[a]

	Spray-dried Porcine Plasma, %					
Item	5	7.5	10	12.5	15	CV
d 0 to 14						
ADG, lb[b]	.45	.46	.47	.48	.50	10.0
ADFI, lb[c]	.48	.49	.51	.51	.55	7.8
F/G	1.09	1.05	1.08	1.08	1.11	6.3
d 14 to 21						
ADG, lb[c]	.77	.71	.68	.63	.63	6.9
ADFI, lb[d]	.93	.88	.85	.80	.83	10.7
F/G[d]	1.22	1.24	1.27	1.28	1.33	13.0
d 14 to 25						
ADG, lb	.78	.75	.73	.69	.74	9.9
ADFI, lb	.96	.93	.91	.86	.91	9.6
F/G	1.23	1.25	1.26	1.26	1.23	6.2
d 0 to 25						
ADG, lb	.59	.59	.59	.57	.61	8.3
ADFI, lb	.69	.68	.68	.66	.71	7.6
F/G	1.17	1.16	1.17	1.17	1.17	4.4
d 25 to 42						
ADG, lb	.95	.94	.90	.90	.95	5.4
d 0 to 42						
ADG, lb	.74	.72	.71	.70	.74	5.0

[a] Two hundred ninety weanling pigs were used (initially 7.6 lb and 10.5 d of age), 9 or 10 pigs/pen, 6 pens per treatment. Experimental diets were fed from d 0 to 14 postweaning. All pig were fed common diets from d 14 to 42 postweaning.
[b,c,d] Linear effects (P<.06, .01, .04, respectively).

Table 3. Weights of Pigs Fed Various Levels of Spray-dried Porcine Plasma[a]

	Spray-dried Porcine Plasma, %					
Item, lb	5	7.5	10	12.5	15	CV
d 0	7.6	7.6	7.6	7.6	7.6	.42
d 7	9.4	9.7	9.9	9.5	9.8	3.8
d 14[b]	13.9	14.2	14.4	14.3	14.6	4.3
d 21	19.3	19.2	19.1	18.8	19.1	4.9
d 25	22.6	22.5	22.4	22.1	22.8	5.1
d 42	38.8	38.7	37.8	37.6	38.9	3.8

[a] Two hundred ninety weanling pigs were used (initially 7.6 lb and 10.5 d of age), 9 or 10 pigs/pen, 6 pens per treatment. Experimental diets were fed from d 0 to 14 postweaning. All pig were fed common diets from d 14 to 42 postweaning.
[b] Linear effect (P<.06).

SOYBEAN MEAL IS NECESSARY IN DIETS FOR EARLY-WEANED (12 D OF AGE) PIGS[1]

S. S. Dritz, M. D. Tokach, J. L. Nelssen, R. D. Goodband, and K. Q. Owen

Summary

A total of 192 pigs (initially 8.0 lb and 12 d of age) was used to determine the optimal soybean meal level to be included in starter diets for the 12-d-old weaned pig. The trial was a 28 d growth assay. Pigs were allotted by weight to six replicates of four treatments with six or 10 pigs per pen. From d 0 to 14 postweaning, pigs were fed a common diet or experimental diets containing 5, 10, and 15% soybean meal. These high nutrient dense diets were formulated to contain 1.7% lysine. All pigs were fed a common transition diet from d 14 to 21 postweaning formulated to contain 1.4% lysine and a common phase II diet from d 21 to 28 postweaning formulated to contain 1.25% lysine. Linear improvements in average daily gain (ADG) and average daily feed intake (ADFI) were observed in the d 0 to 14 postweaning period as soybean meal increased from 0 to 15% of the diet. No differences in growth performance were observed when pigs were fed the common transition and phase II diets from d 14 to 21 postweaning and d 21 to 28 postweaning, respectively. Pig weights on d 14, 21, and 28 postweaning improved linearly. Thus, the improvements in ADG and ADFI for the cumulative (d 0 to 28 postweaning) period were a result of the performance in the d 0 to 14 postweaning period. The advantage in pig weight on d 14 postweaning was maintained through d 28 postweaning. In conclusion, soybean meal can replace skim milk and be included at a level between 10 and 15% in the diet of pigs weaned at 12 d of age.

(Key Words: Starter, Soybean Meal, Skim Milk.)

Introduction

Early weaning is becoming a common practice in the commercial swine industry in disease elimination programs and to increase productivity. Weaning pigs at 5 to 10 d of age requires diets that are highly digestible and palatable. Previous research at Kansas State University has suggested that decreased growth performance during the first week postweaning of pigs weaned at 21 d of age can be attributed to an immune (allergic) reaction to soybean meal proteins in the small intestine. This reaction is thought to occur after the piglets immune system is exposed to small amounts of soybean meal protein preweaning. Further research indicated that feeding pigs weaned at 21 d of age a diet without soybean meal postweaning followed by a diet with soybean meal results in a similar decreased growth performance. This indicates that some soy protein is required in the first diet postweaning for the development of tolerance. Thus, the objective of this experiment was to determine the optimal level of soybean meal in the diet for early-weaned (12 d of age) pigs.

Procedures

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[1] The authors wish to thank Steve and Brent Eichman and Eichman Farms, St. George, KS for use of animals and facilities for this experiment.

A total of 192 pigs (initially 8.0 lb and 12 d of age) was used to determine the optimal soybean meal level to be included in starter diets for the early-weaned pig (12 d of age). The trial was a 28 d growth assay. From d 0 to 14 postweaning, pigs were fed a control diet of experimental diets containing 5, 10, and 15% soybean meal (Table 1). Soybean meal and lactose replaced dried skim milk to provide the three soybean meal diets. The diets were formulated to contain 1.7% lysine and .49% methionine. Lactose was added to ensure that all four diets were equal in lactose content. From d 14 to 21 postweaning, all pigs were fed a common transition diet formulated to contain 1.4% lysine .40% methionine (Table 1). This diet contained 20% dried whey, 2.5% spray-dried porcine plasma, and 2.5% spray-dried blood meal. From d 21 to 28 postweaning, all pigs were fed a common phase II diet formulated to contain 1.25% lysine and .36% methionine (Table 1). This diet contained 10% dried whey and 2.5% spray-dried blood meal. Pigs were housed in an environmentally controlled nursery with ad libitum access to feed and water. Pigs were housed 6 or 10 pigs per pen and six replicate pens per treatment. Weekly pig weights and feed consumption were collected to determine ADG, ADFI, and feed efficiency (F/G).

Results and Discussion

For the d 0 to 14 postweaning period, ADG and ADFI increased (linear, P<.01) as the level of soybean meal was increased from 0 to 15% (Table 2). For the transition (d 14 to 21 postweaning) and phase II periods, no differences occurred in ADG, ADFI, and F/G, indicating no effect of diet fed from d 0 to 14 postweaning on subsequent performance in the transition or phase II periods. This resulted in a linear (P<.02) improvement in pig weights on d 14, 21, and 28 postweaning (Table 3). Pigs fed 10% soybean meal were 14% heavier than pigs fed control diet on d 14 postweaning. Cumulative (d 0 to 28 postweaning) ADG improved (linear, P<.02) and ADFI tended to improve (quadratic, P<.08, linear, P<.07) as the level of soybean meal increased from 5 to 15% of the diet. Thus, the improvements in ADG and ADFI for the cumulative period (d 0 to 28 postweaning) were a result of the performance in the d 0 to 14 postweaning period.

Results of this experiment indicate that no adverse immune reaction to soybean meal protein occurred when compared to dried skim milk. Two possible explanations are the pigs had been weaned before they were sensitized to soybean meal protein or the young pigs' immune system had not developed enough to cause an adverse reaction. The results also suggest a negative influence of skim milk on the feed intake of pigs weaned at 12 d of age. In conclusion, soybean meal can be included at a level between 10 and 15% in the diet of pigs weaned at 12 d of age.

Table 1. Diet Composition[a]

		Soybean Meal, % - Phase I				
Item, %	Control	5	10	15	Transition	Phase II
Corn	32.53	30.20	27.88	25.55	44.86	61.12
Dried skim milk	20.24	14.33	8.42	2.51	--	--
Soybean meal, (48% CP)	--	5.00	10.00	15.00	20.91	21.94
Lactose	--	3.00	6.00	9.00	--	--
Dried whey , edible grade	25.00	25.00	25.00	25.00	20.00	10.00
Spray-dried porcine plasma	7.50	7.50	7.50	7.50	2.50	--
Fish meal, select menhaden	4.50	4.50	4.50	4.50	--	--
Spray-dried blood meal	1.75	1.75	1.75	1.75	2.50	2.50
Soybean oil	6.00	6.00	6.00	6.00	5.00	--
Monocalcium phosphate (21% P)	.80	.96	1.13	1.29	1.79	1.92
Limestone	.05	.10	.16	.21	.70	.85
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00	1.00
Trace mineral premix	.15	.15	.15	.15	.15	.15
Vitamin premix	.25	.25	.25	.25	.25	.25
DL-methionine	.11	.13	.15	.17	.15	.05
L-lysine HCl	.05	.05	.05	.05	.10	.15
Copper sulfate	.075	.075	.075	.075	.075	.075
Total	100	100	100	100	100	100

[a] The Control and 5, 10, and 15% soybean meal diets were formulated to contain 1.7% lysine and .49% methionine. The transition diet was formulated to contain 1.4% lysine and .40% methionine, and the phase II diet was formulated to contain 1.25% methionine and .36% methionine. All diets were formulated to contain .9% calcium and .8% phosphorus.

[b] Provided 150 g/ton apramycin for the Control and 5, 10, and 15% soybean meal diets. Provided 50 g/ton carbadox in the transition and phase II diets.

Table 2. The Effect of Soybean Meal Level (d 0 to 14 postweaning) on Growth Performance in Diets for Early-weaned Pigs (12 d of age)[a]

		Soybean Meal, %			
Item	Control	5	10	15	CV
d 0 to 14					
ADG, lb[b]	.26	.30	.36	.35	14.4
ADFI, lb[b]	.37	.40	.44	.44	9.4
F/G	1.46	1.36	1.27	1.27	14.7
d 14 to 21					
ADG, lb	.42	.46	.39	.39	11.0
ADFI, lb	.71	.79	.73	.70	11.2
F/G	1.73	1.80	2.06	1.91	18.6
d 21 to 28					
ADG, lb	.93	.98	1.00	1.03	12.9
ADFI, lb	1.57	1.67	1.71	1.69	8.0
F/G	1.69	1.69	1.73	1.66	8.7
d 0 to 28					
ADG, lb[c]	.46	.51	.53	.53	8.3
ADFI, lb[d,e]	.75	.82	.83	.82	6.5
F/G	1.62	1.60	1.60	1.55	5.7

[a] Each number represents the mean of six pens (6 or 10 pigs/pen) with an average initial weight of 8.1 lb and 12 d of age.
[b,c,d] Linear effect (P<.01,.02, and .07 respectively).
[e] Quadratic effect (P<.08).

Table 3. The Effect of Soybean Meal Level from d 0 to 14 Postweaning on Pig Weights[a]

		Soybean Meal, %			
Weight, lb	Control	5	10	15	CV
d 0	8.1	8.1	8.1	8.1	--
d 14[b]	11.7	12.3	13.3	12.9	5.3
d 21[b]	14.7	15.5	16.0	15.7	4.6
d 28[b]	21.2	22.3	23.0	22.9	5.0

[a] Each number represents the mean of six pens (6 or 10 pigs/pen) with an average initial weight of 8.1 lb and 12 d of age.
[b] Linear effect (P<.02).

THE EFFECT OF INCREASING DIETARY METHIONINE ON PERFORMANCE OF THE EARLY-WEANED PIG[1]

K. Q. Owen, J. L. Nelssen, R. D. Goodband, M. D. Tokach, L. J. Kats, and K. G. Friesen

Summary

A total of 216 pigs (initially 10.8 lb and 21 d of age) was used in a 35 d growth trial to determine the effect of increased dietary methionine on growth performance for the early-weaned pig when offered a porcine plasma-based diet. During d 0 to 21 postweaning, increasing methionine levels were obtained by adding DL-methionine to a common basal diet. The control diet was corn-soybean meal-based; contained 10% spray-dried porcine plasma (SDPP), 20% dried whey, 3% lactose, and 1.75% spray-dried blood meal (SDBM); and was formulated to contain 1.6% lysine and .28% methionine. DL-methionine replaced sucrose in the control diet to achieve the experimental dietary methionine levels of .28, .32, .36, .40, .44, and .48%. Six pigs were housed per pen with six pens per treatment. From d 21 to 35 postweaning, all pigs were switched to a common diet containing 10% dried whey and 2.5% SDBM and formulated to contain 1.25% lysine. During d 0 to 21, average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) were improved quadratically as dietary methionine increased, with maximum growth performance being obtained between .40 and .44% dietary methionine. Average daily gain was not affected during the second half (d 21 to 35) of the trial. However, both ADFI and feed efficiency were improved with increasing methionine level fed during phase I. On d 7 and 14 postweaning, blood urea N was reduced as dietary methionine increased. Pigs fed .40% dietary methionine had the lowest blood urea N concentration on d 14 compared to pigs fed the other methionine levels. Cumulative (d 0 to 35) ADG and ADFI were maximized between .40 and .44% dietary methionine. These data suggest that the early-weaned pig requires approximately .40 to .44% dietary methionine to optimize growth performance. This corresponds to .345 to .385% digestible methionine and 1.27 and 1.55 g/d of methionine intake from d 0 to 14 postweaning. These requirements are substantially higher than those previously recommended.

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

Introduction

The recent addition of high levels of SDPP and SDBM to starter pig diets has generated interest in the need for synthetic methionine additions. Both of these protein sources are deficient in methionine. Recently, two trials conducted at Kansas State University demonstrated that DL-methionine is essential to maximize growth performance and feed efficiency when spray-dried blood products are included in starter pig diets. However, no research has been conducted addressing the methionine requirement when spray-dried blood products are included in the phase I high nutrient dense diet (HNDD). Therefore, this re-

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[1] The authors would like to thank the Degussa Corp., Allendale, NJ for providing the amino acids used in this experiment.

search was conducted to determine the effect of increased dietary methionine on growth performance for the early-weaned pig when offered a porcine plasma-based diet.

Procedures

Two hundred and sixteen pigs (initially 10.8 lb and 21 d of age) were randomly allotted by weight to one of six experimental treatments. Throughout the first 21 d of the experiment, pigs were fed diets containing either .28, .32, .36, .40, .44, or .48% dietary methionine (Table 1). When expressed on a digestible amino acid basis, corresponding methionine levels were .225, .265, .305, .345, .385, and .425%. A control diet was formulated to contain 1.6% lysine (1.37% digestible lysine), .28% methionine, .90% calcium, and .80% phosphorus. Sucrose was replaced by DL-methionine to achieve the experimental methionine levels. Because cystine can meet half the total sulphur amino acid requirement, cystine content of all diets was .62%. This exceeds the amount needed to meet the highest level of methionine (based on a 50:50 mixture of methionine and cystine). To ensure that methionine was first limiting, dietary isoleucine, threonine, and tryptophan were maintained relative to lysine according to the ratio proposed by researchers at the University of Illinois for the 11 to 22 lb pig. Additionally, choline chloride was supplemented to all diets at .10%. The levels of corn, soybean meal, dried whey (20%), SDPP (10%), and SDBM (1.75%) remained constant in all experimental diets.

There were six pens per treatment with six pigs/pen. Pigs were housed in 3.5 ft × 5 ft pens with woven wire flooring. Each pen had a self-feeder and nippled waterer to allow ad libitum consumption of feed and water. Pigs and feeders were weighed on d 7, 14, 21, and 35 to allow calculation of ADG, ADFI, and F/G. Blood samples were taken on day 7, 14, and 21 to determine blood urea N. On d 21, all pigs were switched to a common diet containing 10% dried whey and 2.5% SDBM and formulated to contain 1.25% lysine. This diet was fed from d 21 to 35 postweaning.

Data were analyzed as a randomized complete block design. General linear model procedures were used, with initial weight, sex and ancestry serving as the blocking factors. Orthoganol polynomial contrasts were used to determine linear and quadratic effects.

Results and Discussion

During d 0 to 21 postweaning, ADG, ADFI, and feed efficiency were improved quadratically (P<.01) when dietary methionine increased. Plateaus in ADG and ADFI were detected at approximately .44% dietary methionine, whereas feed efficiency reached a plateau at approximately .40 to .44% dietary methionine. When the dietary methionine requirement (.44%) is expressed as a percentage of lysine (1.60%), this ratio of methionine to lysine is approximately 28%. This is similar to the ratio proposed by researchers at the University of Illinois but, higher than a lysine to methionine ratio suggested by the NRC (1988). Additionally, this methionine requirement is substantially higher than that previously recommended for use in the KSU phase I high nutrient density diet.

From d 21 to 35 (when a common diet was fed), no treatment effects were detected for ADG when dietary methionine levels increased during d 0 to 21. However, quadratic responses were observed for ADFI (P<.07) and feed efficiency (P<.08). During this phase, an interesting observation was noted. Pigs on the two lowest methionine levels (.28 and .32%) during d 0 to 21 were 10 and 7% more efficient than pigs receiving the diet containing .44% dietary methionine, respectively. However, overall (d 0 to 35) ADG and ADFI were improved quadratically (P<.01) and appeared to be maximized at approximately .44% dietary methionine. Although no differences were observed for feed efficiency, F/G appeared to be optimized at .40%

dietary methionine. The responses observed for the entire trial were the same responses seen during d 0 to 21, indicating that the performance during this first phase is very crucial for the overall performance. On d 35, pigs receiving the diet containing .44% dietary methionine were 20 and 5% heavier than those consuming the diets containing .28 or .32% dietary methionine, respectively.

On d 7 and 14, blood urea N was reduced quadratically as dietary methionine increased (Table 2). Pigs fed .40% dietary methionine had the lowest blood urea N concentration on d 14 when compared to the other treatments.

These data suggest that the early-weaned pig requires approximately .40 to .44% dietary methionine to maximize growth performance. This corresponds to .345 to .385% digestible methionine and 1.27 and 1.55 g/d of methionine intake from d 0 to 14 postweaning. These requirements are substantially higher than those previously recommended.

Table 1. Control and Phase II Diet Composition,%[a]

Ingredient	Control	Phase II
Corn	41.17	58.92
SBM, 48.5%	14.28	21.03
Dried whey	20.00	10.00
Porcine plasma	10.00	--
Lactose	3.00	--
Soybean oil	5.00	3.00
Monocalcium phosphate	2.01	1.97
Spray dried blood meal	1.75	2.50
Antibiotic[b]	1.00	1.00
Limestone	.66	.83
Vitamin premix	.25	.25
Mineral premix	.15	.15
L-lysine	.12	.15
Copper sulfate	.08	.08
Sucrose[c]	.20	--
DL-methionine	--	.06
L-isoleucine	.14	--
L-cystine	.06	--
L-threonine	.03	--
Choline chloride	.10	--
Total	100.0	100.0
<u>Calculated Analysis, %</u>		
Lysine	1.60	1.25
Methionine	.28	.33
Cystine		.56.34
Threonine	.91	.80
Tryptophan	.23	.24
Isoleucine	.81	.75

[a] Control diet (phase I) was formulated to contain 1.6% lysine, .28% methionine, .90% Ca, and .80% P, and the phase II diet contained 1.25% lysine.
[b] Provided 50 g/ton carbadox.
[c] DL-methionine replaced sucrose to provide .32, .36, .40, .44%, and .48% dietary methionine in experimental diets.

Table 2. The Effect of Increased Dietary Methionine on Growth Performance and Serum Urea Nitrogen in the Early-Weaned Pig[a]

	Dietary Methionine,%						
Item	.28	.32	.36	.40	.44	.48	CV
d 0 to 14							
ADG[b,d]	.40	.58	.68	.70	.76	.69	9.2
ADFI[b,d]	.50	.64	.71	.70	.78	.71	8.3
F/G[b,d]	1.26	1.11	1.03	1.00	1.02	1.04	6.3
d 0 to 21							
ADG[b,d]	.54	.74	.79	.82	.87	.80	7.7
ADFI[b,d]	.71	.88	.92	.91	.98	.92	7.9
F/G[b,d]	1.33	1.18	1.16	1.10	1.13	1.16	6.0
d 21 to 35							
ADG	1.03	1.12	1.07	1.10	1.05	1.08	11.9
ADFI[c,e]	1.66	1.84	1.98	1.92	1.87	1.88	9.6
F/G[c,f] 1.61	1.65	1.87	1.75	1.78	1.76	9.1	
d 0 to 35							
ADG[b,d]	.74	.89	.90	.93	.94	.91	8.2
ADFI[b,d]	1.09	1.26	1.34	1.31	1.34	1.31	7.9
F/G	1.48	1.42	1.49	1.40	1.42	1.44	4.5
Serum urea N, mg/dl							
d 7[b,d]	13.16	7.68	5.87	5.45	5.48	5.34	39.6
d 14[b,d]	8.79	7.42	5.67	4.45	4.95	4.48	20.1
d 21[b]	10.25	8.72	8.61	7.28	9.33	6.60	22.1

[a] Two hundred and sixteen weanling pigs were used (initially 10.8 lbs and 21 d of age), 6 pigs/pen with 6 pens per treatment.

[b,c] Linear effects of dietary methionine (P<.01) and (P<.10), respectively.

[d,e,f] Quadratic effects of dietary methionine (P<.01), (P<.05), and (P<.10), respectively.

THE EFFECTS OF INCREASING DIETARY METHIONINE IN THE PHASE II STARTER PIG DIET[1]

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Summary

A total of 216 pigs (initially 12.4 lb and 21 d of age) was used in a 28 d growth trial to determine the effects of increasing dieatary methionine in the phase II (d 7 to 28 postweaning) diet. Pigs were allotted by sex, weight, and ancestry and placed in pens containing six pigs each. All pigs were offered a common phase I diet for the first 7 d postweaning. The phase I diet contained 20% dried whey, 10% spray-dried porcine plasma (SDPP), 3% lactose, and 1.75% spray-dried blood meal (SDBM) and was formulated to contain 1.6% lysine and .44% methionine. After the phase I period, pigs were assigned to one of six treatments that contained either .27, .30, .33, .36, .39, or .42% dietary methionine. Methionine levels were obtained by adding increasing levels of DL-methionine to a common basal diet. The control diet was corn-soybean meal-based, contained 10% dried whey and 3% SDBM, and was formulated to contain 1.3% lysine and .27% methionine. During phase I (d 0 to 7 postweaning), average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) were .68 lb, .67 lb, and 1.01, respectively. During the first week of phase II (d 7 to 14 postweaning), increasing dietary methionine resulted in improved ADG, ADFI, and F/G. For the cumulative period (d 7 to 28 postweaning), ADG and ADFI were not influenced by increasing dietary methionine; however, F/G was improved and appeared to be maximized at .36% methionine. These data suggest that the early-weaned pig requires .36% dietary methionine during d 7 to 28 postweaning to maximize growth performance when fed a diet containing 1.3% lysine. Also, when expressed relative to lysine, this represents a methionine:lysine ratio of 28%. This corresponds to the same methionine to lysine ratio found to optimize performance during the phase I trial.

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

Introduction

Recent work at Kansas State University has shown the methionine level in the phase I high nutrient dense diet (HNDD) to be substantially higher than the level previously being recommended. One of the primary reasons for a higher methionine requirement is the high level of blood products included in this phase I HNDD. Typically, if pigs are weaned at 21-d of age, they are fed the phase I diet for 1 week (21 to 28 d of age). A phase II diet is then fed for 2 to 3 weeks (28 to 49 d of age). Spray-dried blood meal has become a common protein source in the phase II diet. Because SDBM is deficient in methionine, DL-methionine is being added to this diet. However, results of the recent trial mentioned above have led us to question whether the methionine requirement in this diet is much higher than those currently being recommended. Thus, our objective was to determine the optimal

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[1] The authors would like to thank Novus International, Inc., St. Louis, MO for financial support of this trial.

methionine level in the phase II starter diet.

Procedures

A total of 216 pigs (initially 12.4 lb and 21 d of age) were used in a 28 d growth trial. Pigs were allotted by sex, ancestry, and weight and placed in pens containing 6 pigs/pen. A common phase I diet was fed for the first 7 days postweaning. The phase I diet contained 20% dried whey, 10% SDPP, 3% lactose, and 1.75% SDBM and was formulated to 1.6% lysine and .44% methionine. After the phase I period, pigs were randomly assigned to one of six dietary treatments in a randomized complete block design. Throughout phase II (d 7 to 28 postweaning), pigs were fed diets containing either .27, .30, .33, .36, .39 or .42% total dietary methionine (Table 1). When expressed on a digestible basis, corresponding methionine levels were .249, .279, .309, .339, .369, and .399%. A basal diet was formulated to contain 1.3% lysine (1.09% digestible lysine), .27% methionine, .90% calcium, and .80% phosphorus. Sucrose was replaced by synthetic DL-methionine to achieve the experimental methionine levels. Because cystine can meet half the total sulphur amino acid requirement, cystine content of all diets was .51%. This exceeds the amount needed to meet the highest level of methionine (based on a 50:50 mixture of methionine and cystine). To ensure that methionine was first limiting, dietary isoleucine, threonine, and tryptophan were maintained relative to lysine according to the ratio proposed by researchers at the University of Illinois for the 20 lb pig. Additionally, choline chloride was supplemented to all diets at .10%. The levels of corn, soybean meal, dried whey (10%) and SDBM (1.75%) remained constant in all experimental diets.

There were six pigs/pen with six pens per treatment. Pigs were housed in 3.5 ft × 5 ft pens with woven wire, expanded metal flooring. Each pen had a self-feeder and nippled waterer to allow ad libitum consumption of feed and water. Pigs and feeders were weighed on d 7, 14, 21, and 28 to allow calculation of ADG, ADFI, and F/G. Blood samples were taken on day 14 and 28 to determine blood urea N and amino acids concentrations.

Data were analyzed as a randomized complete block design. General linear model procedures were used with initial weight, sex, and ancestry serving as the blocking factors. Orthoganol polynomial contrasts were used to determine linear and quadratic effects.

Results and Discussion

During Phase I, ADG, ADFI, and F/G were .68 lb, .67 lb, and 1.01, respectively. From d 7 to 14 postweaning, increasing dietary methionine quadratically improved ADG (P<.01), ADFI (P<.05) and F/G (P<.05), with these response criteria appearing to be optimized at .36% dietary methionine. When expressed relative to lysine, with dietary methionine at .36% and dietary lysine at 1.3%, a ratio of 28% methionine to lysine was found. This is the same ratio found to optimize performance during phase I. Additionally, this is similar to the ratio suggested by researchers at the University of Illinois. Comparing the performance of pigs receiving .36% dietary methionine to pigs receiving .27 dietary methionine (which is close to the NRC (1988) estimates) showed improvements of 27%, 10%, and 29% for ADG, ADFI, and F/G, respectively.

From d 7 to 28 postweaning, increasing dietary methionine had no effect on ADG or ADFI, but F/G was quadratically (P<.05) improved. Even though ADG was not significantly influenced, pigs receiving the .36% dietary methionine treatment had the highest numerical value for ADG and were the most efficient (F/G).

Plasma urea N was not affected by dietary treatment. However, pigs receiving .33% and .36% dietary methionine had the lowest numerical values on d 14 postweaning. Pigs receiving the diet containing .30% dietary methionine had the lowest numerical value on d 28 postweaning.

These data suggest that the early-weaned pig requires .36% dietary methionine during d 7 to 28 postweaning to maximize growth performance when fed a diet containing 1.3% lysine. This corresponds to .339 digestible methionine. Also, when expressed on a ratio relative to lysine, this represents a methionine:lysine ratio of 28%. This corresponds to the same methionine to lysine ratio found to optimize performance during the phase I trial. These findings along with the phase I findings suggest that a methionine to lysine ratio of 28% is needed in diets fed to the early-weaned pig.

Table 1. Phase I and Basal Diet Composition, %[a]

Ingredient	Phase I	Basal
Corn	41.17	55.41
SBM, 48.5%	14.28	--
SBM, 44%	--	23.32
Dried whey	20.00	10.00
Porcine plasma	10.00	--
Lactose	3.00	--
Soybean oil	5.00	3.00
Monocalcium phosphate	2.01	1.94
Blood meal	1.75	3.00
Antibiotic[b]	1.00	1.00
Limestone	.66	.81
Vitamin premix	.25	.25
Mineral premix	.15	.15
L-lysine	.12	.15
Copper sulfate	.08	.08
Sucrose[c]	.04	.46
DL-methionine	.16	.06
L-isoleucine	.14	.02
L-cystine	.06	.28
L-threonine	.03	.04
Choline chloride	.10	.10
Total	100.0	100.0
Calculated Analysis, %		
Lysine	1.60	1.30
Methionine	.44	.27
Cystine	.56	.51
Threonine	.91	.85
Tryptophan	.23	.25
Isoleucine	.81	.78

[a] Phase I diets were formulated to contain 1.6% lysine, .28% methionine, .90% Ca, and .80% P; the phase II basal diet contained 1.30% lysine, .27% methionine, .90% Ca, and .80% P.

[b] Provided 50 g/ton carbodox.

[c] DL-methionine replaced corn starch on a lb/lb basis to achieve the .30, .33, .36, and .39% dietary methionine experimental diets.

Table 2. The Effect of Increased Dietary Methionine in the Phase II Diet on Growth Performance and Serum Urea Nitrogen[a]

	Dietary Methionine,%						
Item	.27	.30	.33	.36	.39	.42	CV
d 7 to 14							
ADG[c,d]	.40	.41	.50	.54	.53	.43	18.7
ADFI[e]	.87	.92	.97	.97	.96	.90	9.5
F/G[b,f]	2.53	2.42	1.99	1.80	1.85	2.13	16.6
d 7 to 28							
ADG	.88	.93	.95	.97	.92	.93	9.6
ADFI	1.47	1.47	1.55	1.51	1.51	1.52	7.8
F/G[e]	1.68	1.59	1.63	1.56	1.63	1.65	5.1
Serum urea N, mg/dl							
d 14	5.86	5.78	4.94	5.17	5.36	5.23	21.7
d 28	8.25	6.46	7.01	6.98	7.78	6.95	25.9

[a] Two hundred and sixteen weanling pigs were used (initially 12.4 lbs and 21 d of age), 6 pigs/pen with 6 pens per treatment. Pigs were fed a common phase I diet (d 0 to 7 postweaning).

[bc] Linear effects of dietary methionine (P<.05) and (P<.10), respectively.

[def] Quadratic effects of dietary methionine (P<.01), (P<.05), and (P<.10), respectively.

APPROPRIATE LEVEL OF LACTOSE IN A PLASMA PROTEIN-BASED DIET FOR THE EARLY-WEANED PIG[1]

K. Q. Owen, J. L. Nelssen, M. D. Tokach, R. D. Goodband, S. S. Dritz, and L. J. Kats

Summary

A total of 367 weanling pigs (initially 11.8 lb and 21 d of age) was used in a 28 d growth assay to determine the appropriate level of lactose needed in phase I diets containing spray-dried porcine plasma (SDPP) for the early-weaned pig. Pigs were blocked by weight and randomly assigned to one of six experimental diets: a positive control or five diets calculated to contain 7, 11, 15, 19, or 23% lactose. The positive control was a high nutrient density diet (HNDD) containing 7.5% SDPP, 1.75% spray-dried blood meal (SDBM), and 20% edible grade dried whey. The five lactose diets were achieved by adding lactose to a common basal diet containing 10% edible grade dried whey, 7.5% SDPP, and 1.75% SDBM. Because whey contains approximately 72% lactose, total lactose levels of 7, 11, 15, 19, or 23% were achieved by not adding any or adding 4, 8, 12, or 16% lactose, respectively, to the basal diet. All diets contained 1.5% lysine, .9% calcium and .8% phosphorus. Pigs were fed pelleted diets from d 0 to 14 postweaning. On d 14, all pigs were switched to a common phase II diet containing 10% edible grade dried whey and 2.5% SDBM and formulated to contain 1.25% lysine. Pigs were fed this diet in a meal form for the remainder of the trial (d 14 to 28 postweaning). A linear response occurred for average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) during phase I, with pigs receiving the diet containing the highest level of lactose (23%) having the greatest growth performance. Pigs receiving the diet containing the highest level of lactose also had better daily gains and daily feed intakes when compared to pigs receiving the positive control diet. However, feed efficiency was similar between these two treatments. During phase II, no differences occurred in ADG and F/G, but a linear increase was observed for daily feed intake. Over the total trial, a linear improvement was observed in all performance criteria (ADG, ADFI, and F/G) with increasing dietary lactose. Furthermore, pigs consuming the highest level of lactose had higher daily gain and consumed more feed per day when compared to pigs offered the positive control diet. Results from this research indicate that starter pig performance is improved linearly as lactose levels increase from 7 to 23% in a phase I nursery diet.

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

Introduction

Recent research at Kansas State University has demonstrated that adding spray-dried porcine plasma to diets for the early-weaned pig increases daily gain and feed intake by approximately 25% compared with pigs fed dried skim milk. In this research, 20% dried skim milk was replaced

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[1] Appreciation is expressed to Land-O-Lakes, Inc. for donating feed ingredients and for partial financial support. The authors also wish to thank Steve Eichman and Eichman Farms, St. George, KS for the use of facilities and animals in this experiment.

in the high nutrient density diet with 10% spray-dried porcine plasma (SDPP) and 10% lactose. Because SDPP has replaced dried skim milk in the phase I diet, questions have risen concerning the optimal lactose level. Therefore, this experiment was designed to determine the appropriate level of lactose for a plasma protein starter diet for the early-weaned pig.

Procedures

A total of 367 weanling pigs (initially 11.8 lb and 21 d of age) was used on a commercial swine operation to evaluate various levels of lactose in the phase I diet. Pigs were blocked by weight to one of six experimental treatments. Pigs were housed (six to eight pigs per pen with eight pens per treatment) in an environmentally controlled nursery in 5 x 7 ft pens with metal flooring and allowed ad libitum access to feed and water. Pigs and feeders were weighed weekly after weaning to determine ADG, ADFI, and F/G.

Experimental diets (Table 1) were fed in two phases. During phase I, pigs were offered one of six dietary treatments. Experimental treatments consisted of a positive control diet (equivalency of 14.5% lactose from dried whey) and five other diets containing 7, 11, 15, 19, or 23% total lactose. The positive control diet was a HNDD containing 7.5% SDPP, 1.75% SDBM, and 20% edible grade dried whey. Total lactose levels (7, 11, 15, 19, and 23%) were achieved by not adding any or adding increasing levels of dried lactose (4, 8, 12, 16%) to a common basal diet containing 10% edible grade dried whey, 7.5% SDPP, and 1.75% SDBM. The diet with no added lactose (negative control) contained a total of 7% lactose because whey (present in basal diet) contains approximately 72% lactose. A constant level of soybean meal (21.54%) was added to each diet, and thus, synthetic lysine and methionine were added to all experimental treatments to ensure that all phase I diets contained 1.5% lysine and .38% methionine.

A common diet was fed to all pigs during phase II (d 14 to 28 postweaning). It was corn-soybean meal- based and contained 2.5% SDBM and 10% edible grade edible grade dried whey. All phase I diets were pelleted, whereas the common phase II diet was offered in a meal form.

Results and Discussion

During phase I (d 0 to 14 postweaning), linear (P<.01) improvements occurred for ADG, ADFI, and F/G, with pigs receiving the highest level of lactose (23%) having the greatest performance (Table 2). Additionally, pigs receiving the highest level of lactose (23%) had greater daily gain (P<.05) and consumed more feed per day (P<.08) when compared to pigs consuming the positive control diet. However, no differences occurred in feed efficiency between pigs receiving these two treatments.

During phase II, when a common diet was fed, no differences occurred in growth performance with the exception of ADFI. A linear improvement was observed in ADFI (P<.05), which was similar to results observed during phase I. Also, pigs consuming the diet containing the highest level of lactose (23%) during phase I continued to consume more feed per day (P<.07) during phase II than pigs fed the positive control diet during phase I.

Over the entire trial, a linear improvement (P<.01) was observed in all performance criteria (ADG, ADFI and F/G) with increasing lactose levels. Pigs consuming the diet with the 23% lactose had greater daily gains (P<.03) and consumed more feed per day (P<.04) when compared to pigs receiving the positive control diet.

Results from this research indicate that during phase I and from 0 to 28 d postweaning, pig performance is improved linearly as lactose levels increase from 7 to 23% of the diet. In order to meet the highest level of lactose (23%) with edible grade dried whey, a diet needs to contain at least 32% edible grade dried whey. However, the price of products supplying lactose will dictate the level added in the phase I diet. Also, because a quadratic response was never achieved, additional research is needed addressing the optimal level of lactose needed in the phase I HNDD to provide optimal growth performance.

Table 1. Diet Composition[a]

	Positive	Lactose,% - Phase I					
Item	Control	7	11	15	19	23	Phase II
Corn	42.07	46.83	42.78	38.73	34.68	30.62	58.92
Edible grade dried whey	20.00	10.00	10.00	10.00	10.00	10.00	10.00
Soybean meal, 48.5%	16.39	21.54	21.54	21.54	21.54	21.54	21.03
Soy oil	8.00	8.00	8.00	8.00	8.00	8.00	3.00
Lactose	--	--	4.00	8.00	12.00	16.00	--
Porcine plasma	7.50	7.50	7.50	7.50	7.50	7.50	--
Monocalcium phosphate	1.95	2.09	2.14	2.19	2.25	2.30	1.97
Spray dried blood meal	1.75	1.75	1.75	1.75	1.75	1.75	2.50
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	.67	.76	.74	.71	.69	.67	.83
Vitamin premix	.25	.25	.25	.25	.25	.25	.25
Mineral premix	.15	.15	.15	.15	.15	.15	.15
L-lysine HCl	.10		.01	.03	.04	.05	.15
DL-methionine	.10	.05	.06	.07	.08	.08	.06
Copper sulfate	.08	.08	.08	.08	.08	.08	.08
Isoleucine	--	--	--	--	--	.01	--
Total	100	100	100	100	100	100	100

[a] Diets were formulated to contain 1.5% lysine, at least .81% isoleucine, and at least .37% methionine in Phase I and 1.25% lysine in Phase II.

[b] Provided 150 g/ton apramycin in Phase I and 50 g/ton carbadox in Phase II.

Table 2. Growth Performance of Pigs Fed the Positive Control Diet and Pigs Fed Diets Containing Various Levels of Lactose[a]

Item	Positive Control	Lactose,% 7	11	15	19	23	CV
d 0 to 14							
ADG[b,d]	.51	.44	.46	.54	.52	.58	12.5
ADFI[b,e]	.58	.54	.59	.59	.60	.63	9.7
F/G[b]	1.15	1.27	1.30	1.14	1.16	1.11	13.6
d 14 to 28[f]							
ADG	1.01	.97	1.04	1.01	.99	1.07	9.3
ADFI[c,e]	1.53	1.51	1.53	1.56	1.55	1.64	7.5
F/G	1.51	1.57	1.49	1.54	1.56	1.52	5.0
d 0 to 28							
ADG[b,d]	.77	.71	.75	.78	.76	.83	7.3
ADFI[b,d]	1.06	1.04	1.07	1.09	1.09	1.15	7.2
F/G[b]	1.39	1.48	1.42	1.40	1.42	1.38	3.6

[a] A total of 367 weanling pigs was used (initially 11.8 lbs and 21 d of age), 6 to 8 pigs/pen with 8 pens per treatment.

[b,c] Linear effects of lactose (P<.01) and (P<.05), respectively.

[d,e] Positive control vs 23% lactose (P<.05) vs (P<.10), respectively.

[f] Common diet was fed to all pigs from d 14 to 28 postweaning.

SPRAY-DRIED EGG PROTEIN IN DIETS FOR EARLY-WEANED STARTER PIGS

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Summary

A total of 197 weanling pigs (initially 11.7 lb and 18 d of age) was used in a 28 d growth trial to determine the influence of spray-dried egg protein as a protein substitute for either soybean meal or spray-dried porcine plasma on starter pig performance. Pigs were blocked by weight with six replications per treatment and seven to eight pigs per pen. Dietary treatments were based on level of egg protein (3 or 6%) added to a phase I high nutrient dense diet and the method of substitution (egg protein replacing either soybean meal or porcine plasma). A sixth treatment served as an initial test of an egg protein blend. Treatments were as follows: 1) Control, 2 and 3) 3% or 6% egg protein substituted for soybean meal, 4 and 5) 3% or 6% egg protein substituted for spray-dried porcine plasma, and 6) 4% egg protein blend substituted for spray-dried porcine plasma. The control diet contained 7.5% porcine plasma, 1.75% spray-dried blood meal, and 20% dried whey. The egg products were substituted for the soybean meal or the porcine plasma on an equal lysine basis, maintaining the lysine level of all diets at 1.5%. Total added fat was maintained at 5% All pigs were fed a common diet from d 14 to 28 postweaning. During phase I, average daily gain (ADG) indicated that spray-dried egg protein was a suitable substitute for up to 3% porcine plasma or up to 6% soybean meal. However, pigs consuming the diet substituting 6% egg protein for porcine plasma had poorer ADG. Feed efficiency became poorer as spray-dried egg protein was substituted for 6% soybean meal or 3 to 6% porcine plasma. This indicates that the fat in spray-dried egg protein may be less available than soybean oil. Pigs fed the diet containing the 4% egg protein blend had poorer ADG and F/G than pigs fed the control diet. This indicates that 4% egg protein blend cannot effectively replace porcine plasma. These data suggest that spray-dried egg protein can replace at least 6% soybean meal and up to 3% porcine plasma in the phase I diet without reducing ADG; however, further research must be conducted to determine the digestibility of fat in the egg protein product.

Introduction

Recent research at Kansas State University has evaluated several protein sources in diets for early-weaned pigs. These proteins sources include spray-dried porcine plasma, spray-dried blood meal, dried skim milk, and various soy protein concentrates. Spray-dried egg protein has an excellent amino acid profile; however, few data are available evaluating the use of egg protein in starter pig diets. If egg protein proves to be a suitable protein source for the young

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[1] The authors would like to thank American Dehydrated Foods, Inc., St. Louis, MO for providing the egg protein products and for partial funding of the research. The authors also wish to thank Steve Eichman and Eichman Farms St. George, KS for the use of facilities and animals in this experiment.

pig, it could be substituted for porcine plasma to decrease the cost of the diet while improving performance. Therefore, the objective of this experiment was to determine the influence of egg protein substituted for either soybean meal (SBM) or porcine plasma on starter pig performance.

Procedures

A total of 197 pigs (initially 18 d and 11.7 lb) was used in this 28-d growth trial. Pigs were blocked by weight and allotted to one of the six dietary treatments for a total of eight to 10 pigs/pen and six pens/treatment. Dietary treatments were based on level of egg protein (3 or 6%) added to the phase I diet and the method of substitution (egg protein replacing either soybean meal or porcine plasma). A sixth treatment served as an initial test of an egg protein blend. Treatments were as follows: 1) Control, 2 and 3) 3% or 6% egg protein substituted for soybean meal, 4 and 5) 3% or 6% egg protein substituted for spray-dried porcine plasma, and 6) 4% egg protein blend for spray-dried porcine plasma.

The trial was divided into two phases. Experimental diets were fed only during phase I (d 0 to 14 postweaning). All experimental diets were formulated to 1.5% lysine, .9% calcium, .8% phosphorus, and at least .36% methionine. The control diet was a high nutrient density diet containing 7.5% spray-dried porcine plasma, 1.75% spray-dried blood meal, and 20% dried whey. Spray-dried egg protein (3 or 6%) replaced either soybean meal (treatments 2 and 3) or porcine plasma (treatments 4 and 5) on an equal lysine basis. Experimental diet 6 was formulated by replacing porcine plasma in the control diet with 4% egg protein blend on an equal lysine basis. Total fat additions were maintained at 5% with soybean oil or the egg protein products serving as the added fat sources. Experimental diets fed during phase I were pelleted. A common corn-soybean meal-based diet containing 2.5% spray-dried blood meal and 10% dried whey was fed to all pigs during phase II (d 14 to 28 post-weaning). This diet was formulated to 1.25% lysine, .9% calcium, and .8% phosphorus and fed in a meal form.

Pigs were housed in an environmentally controlled nursery in 5 x 7 ft pens. They were allowed ad libitum access to feed and water. Pigs were weighed and feed disappearance were measured on d 7, 14, 21 and 28 after weaning to determine ADG, ADFI, and F/G.

Data were analyzed as a randomized complete block design. General linear model procedures were used with initial weight serving as the blocking factor. Single degree of freedom contrasts were used to separate treatment means.

Results and Discussion

During phase I (d 0 to 14 postweaning), pigs fed diets containing 3% egg for plasma or 3 or 6% for SBM had similar ADG. However, pigs consuming the diets substituting 6% spray-dried egg protein for porcine plasma and 4% egg protein blend for porcine plasma had poorer ADG ($P<.06$ and $P<.03$, respectively). Additionally, feed efficiency was depressed as spray-dried egg protein was substituted for 6% soybean meal ($P<.05$) or 3 ($P<.07$) and 6% ($P<.01$) porcine plasma. Substituting 4% egg protein blend for spray-dried porcine plasma resulted in a 5% poorer F/G when compared to the positive control. These data indicate that the fat in spray-dried egg protein and egg protein blend may be less available than soybean oil.

During phase II (d 14 to 28 post-weaning) and the overall trial, pigs fed the diet substituting 6% spray-dried porcine plasma with spray-dried egg protein had the poorest ADG ($P<.01$) and ADFI ($P<.01$). Over the entire trial, replacing 6% spray-dried porcine plasma with spray-dried egg protein resulted in poorer F/G ($P<.05$)compared with pigs fed the other experimental treatments. Pigs fed all other treatments had similar growth performance. These data imply that replacing 6% spray-dried porcine plasma with spray-dried egg protein depresses performance during both phases (I and II) of production.

In conclusion, decreasing the amount of spray-dried porcine plasma in the phase I diet from 7.5 to 4.5% by replacement with spray-dried egg protein results in a $40/ton reduction in diet cost. Therefore, diet cost can be reduced in phase I and similar average daily gains acquired by replacing 3% spray-dried porcine plasma with spray-dried egg protein. However, these results warrant further investigation addressing the availability of fat in the spray-dried egg protein product.

Table 1. Composition of Diets d 0 to 14 Postweaning[a]

		SBM Substitution		SDPP Substitution		
Ingredient,%	Control	3% Egg[b]	6% Egg[c]	3% Egg[d]	6% Egg[e]	4% EPB[f]
Corn	45.54	46.92	48.31	45.34	45.13	46.78
Soybean meal (48% CP)	15.96	12.67	9.39	15.96	15.96	15.96
Porcine plasma	7.50	7.50	7.50	5.88	4.27	2.88
Egg protein	--	3.00	6.00	3.00	6.00	--
Egg protein blend (EPB)	--	--	--	--	--	4.00
Soybean oil	5.00	3.97	2.93	3.97	2.93	4.20
Dried whey	20.00	20.00	20.00	20.00	20.00	20.00
Spray-dried blood meal	1.75	1.75	1.75	1.75	1.75	1.75
Monocalcium phosphate	1.91	1.89	1.86	1.82	1.72	--
Monosodium phosphate	--	--	--	--	--	.67
Limestone	.69	.67	.66	.67	.66	1.04
Antibiotic[g]	1.00	1.00	1.00	1.00	1.00	1.00
Copper sulfate	.08	.08	.08	.08	.08	.08
L-lysine	.10	.10	.10	.10	.10	.10
DL-methionine	.08	.05	.02	.03	--	--
Vitamin premix	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a] All diets were formulated to contain 1.5% lysine, .9% calcium, .8% phosphorus and at least .365% methionine and .52% sodium.
[b] 3% egg = 3% egg substituted for SBM.
[c] 6%egg = 6% egg substituted for SBM.
[d] 3%egg = 3% egg substituted for spray-dried porcine plasma.
[e] 6%egg = 6% egg substituted for spray-dried porcine plasma.
[f] 4%EPB = 4% egg protein blend substituted for spray-dried porcine plasma.
[g] Provided 150 g of apramyacin per ton of feed.

Table 2. Influence of Spray-Dried Egg Products on Starter Pig Performance[a]

		SBM Substitution		SDPP Substitution			
Item	Control	3% Egg[f]	6% Egg[g]	3% Egg[h]	6% Egg[i]	4% EPB[j]	CV
D 0 to 14							
ADG, lb	.59[b]	.57[b]	.55[b]	.55[b]	.48[c]	.51[c]	12.0
ADFI, lb	.672	.66	.69	.69	.65	.62	9.5
F/G	1.16[b]	1.17[b]	1.25[c]	1.25[c]	1.37[d]	1.22[b,c]	7.1
D 14 to 28							
ADG, lb	1.050[b]	1.00[b]	1.00[b]	1.05[b]	.93[c]	1.03[b]	7.9
ADFI, lb	1.660[b]	1.605[b]	1.54[b]	1.62[b]	1.43[c]	1.60[b]	7.4
F/G	1.58	1.61	1.55	1.54	1.57	1.55	6.1
D 0 to 28							
ADG, lb	.819[b]	.784[b]	.77[b]	.80[b]	.70[c]	.77[b]	7.7
ADFI, lb	1.166[b]	1.131[b]	1.12[b]	1.15[b]	1.04[c]	1.11[b]	7.3
F/G	1.43[b]	1.45[b,c]	1.44[b]	1.44[b]	1.50[c]	1.44[b]	4.6

[a] One hundred and ninety seven weanling pigs were used (initially 11.7 lbs and 21 d of age), 7 to 8 pigs/pen with 6 pens per treatment. All diets were formulated to contain 1.5% lysine, .9% calcium, .8% phosphorus and at least .365% methionine and .52% sodium.

[b,c,d,e] Means within the same row without a common superscript differ ($P<.05$).

[f] 3% egg = 3% egg substituted for SBM.

[g] 6%egg = 6% egg substituted for SBM.

[h] 3%egg = 3% egg substituted for spray-dried porcine plasma.

[i] 6%egg = 6% egg substituted for spray-dried porcine plasma.

[j] 4%EPB = 4% egg protein blend substituted for spray-dried porcine plasma.

THE EFFECTS OF DIETARY SOY PROTEIN SOURCE FED TO THE EARLY-WEANED PIG ON SUBSEQUENT GROWTH PERFORMANCE[1]

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Summary

Two hundred and ninety five pigs (initially 12.3 lb and 21 d of age) were used to determine the effect of different soy protein sources fed during phase I on subsequent growth performance. Dietary treatments were based on different soy protein sources added to the phase I (d 0 to 14 postweaning) diet. Pigs were fed one of five experimental treatments: 1) control diet (casein); 2) moist extruded soy protein concentrate (MESPC); 3) soybean meal (SBM); 4) soy protein concentrate (SPC); 5) moist extruded soy flour (MESF). The phase I diet contained 20% dried whey (DW), 7.5% spray dried porcine plasma (SDPP), and 1.75% spray dried blood meal (SDBM) and was formulated to contain 1.6% lysine, .44% methionine, and 14.4% lactose. From d 14 to 28 postweaning (phase II), all pigs were fed a common (1.25% lysine) corn-SBM diet containing 2.5% SDBM and 10% DW. During phase I, no differences occurred in average daily gain (ADG) or feed efficiency (F/G) between any experimental treatments. However, pigs fed the MESPC-based diet had higher average daily feed intakes (ADFI) when compared to pigs fed either SBM or MESF. From d 14 to 28, pigs fed MESPC during phase I, had higher ADG when compared to the performance of pigs fed SPC and MESF and higher ADFI when compared with pigs receiving the other experimental treatments. Pigs fed SBM during phase I had improved F/G compared to SPC and MESPC. Cumulative data (d 0 to 28 postweaning) indicated that pigs fed the diet containing MESPC during phase I had numerically higher ADG and ADFI when compared to pigs fed the MESF or SPC treatments; however, MESPC pigs were less efficient. Feed cost per pound of gain was the lowest for pigs fed SBM during phase I for overall performance. Pigs fed MESPC in phase I had numerically higher ADG and were 1.4 lb heavier at the end of the trial. However, this advantage would cost an additional $2.00 for feed. In summary, economics and performance must be considered before deciding to use SBM or MESPC in the phase I diet. Our results indicate no advantage in using SPC or MESF in the phase I diet.

Introduction

The appropriate source and level of soybean protein to use in the diet for the early-weaned pig constitute a major controversy in the swine industry. The controversy centers on whether the first diet after weaning should contain any soybean protein, and if soybean protein is used, should it be a further processed soybean product or soybean meal. The answers to these questions have a major impact on the cost of the early weaning diet. This diet typically costs $750 to $1,250 per ton when purchased as a complete feed. From a cost

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[1] Appreciation is expressed to Feed Specialties Inc., Des Moines, IA for donating feed ingredients. The authors also wish to thank Steve Eichman and Eichman farms, St. George, KS for use of facilities and animals in this experiment.

standpoint, it would be advantageous to use soybean meal in this diet.

In previous research at Kansas State University, we demonstrated that pigs fed diets containing high levels of soybean meal during the first 2 weeks postweaning gained slower and less efficiently than pigs fed an all milk-based diet. However, when switched to a common corn-soybean meal diet on d 14 postweaning, pigs that were fed the milk-based diet from d 0 to 14 had decreased ADG and ADFI. Therefore, we concluded that the diet for the early-weaned pig must contain some soybean protein to allow the pig to became adjusted to soybean meal. Further trials indicated that the diet could contain 15 to 20% soybean meal without a severe reduction in performance. However, many nutritionists and most feed companies are worried about adverse reactions to soybean meal and, thus, use a further processed soybean protein (soy protein concentrate, moist extruded soy protein concentrate, or moist extruded soy flour) as the protein source instead of soybean meal. These products increase the cost of the diet by $100 to $150 per ton.

Therefore, this experiment was designed to answer the practical question of whether the complex starter diet for the young pig should contain soybean protein and whether the source of the soy protein should be soybean meal, soy protein concentrate, moist extruded soy protein concentrate or moist extruded soy flour.

Procedures

A total of 295 pigs (initially 12.3 lb and 21-d of age) were used in a 28-d growth assay. Pigs were blocked by weight to give three blocks with six pigs/pen and four blocks with 13 pigs/pen. This was due to the variation in the number of pigs weaned per week on the commercial swine operation in which this experiment was conducted. There were seven pens/experimental treatment.

Experimental diets were fed in two phases. During phase I, pigs were fed one of five experimental diets. Dietary treatments consisted of a control diet that contained casein as the protein source and four other treatments that contained different soy protein sources. The soy protein sources that were evaluated included: 1) moist extruded soy protein concentrate, 2) soybean meal, 3) soy protein concentrate, and 4) moist extruded soy flour. All phase I diets contained 7.5% SDPP, 1.75% SDBM, and 20% DW. Moist extruded soy protein concentrate, SBM, soy protein concentrate, and moist extruded soy flour replaced casein on a equal lysine basis (Table 1). The phase I diet was formulated to contain 1.6% lysine, .44 % methionine, and 14.4% lactose.

A common diet was fed to all pigs during phase II (Table 1). This diet was corn-soybean meal-based and contained 2.5% spray-dried blood meal and 10% dried whey. All phase I diets were fed in a pelleted form. The phase II diet was fed in a meal form.

Pigs were housed in an environmentally controlled nursery room. Temperature was maintained at approximately 90°F for the first week of the trial and lowered approximately 5°F per week to maintain pig comfort. Pigs had ad libitum access to food and water. Pigs were weighed and feed disappearance was recorded on d 7, 14, 21, and 28 postweaning to determine ADG, ADFI, and F/G.

Results and Discussion

During d 0 to 14 postweaning, no differences occurred in ADG and F/G between any treatment means (Table 2). However, pigs receiving the diet containing MESPC had higher (P<.10) ADFI when compared to pigs fed either SBM or MESF. Also during this phase I period, pigs on the SBM treatment had the lowest numerical feed cost per pound of gain.

From d 14 to 28, pigs fed MESPC during phase I had higher ADG (P<.10) when compared with pigs fed SPC and MESF. Additionally, pigs fed MESPC during phase I had greater feed intakes (P<.10) compared with pigs fed other protein sources. However, pigs fed the SBM treatment were the most efficient, with the casein and MESF treatments being intermediate. The pigs fed the SBM treatment also had the lowest feed cost per pound of gain. Cumulative data (d 0 to 28 postweaning) indicate that pigs fed the MESPC during phase I had higher ADG (P<.10) and ADFI (P<.09) when compared to the pigs on the MESF or SPC treatments. No differences occurred in ADG between the casein, MESPC, or SBM treatments. Although, the MESPC treatment had the highest ADFI (P<.10), pigs were less efficient than pigs fed the diet containing SBM. Feed cost per pound of gain over the 28-d growth period was lowest for pigs fed the diet containing SBM.

Pigs fed MESPC in phase I had numerically higher ADG and were 1.4 lb heavier at the end of the trial. However, this advantage would cost an additional $2.00 for feed. In summary, economics and performance must be considered before deciding to use SBM or MESPC in the phase I diet. Our results indicate no advantage in using SPC or MESF in the phase I diet.

Table 1. Diet Composition, %[a]

Item	Casein	MESPC[b]	SBM[c]	SPC[d]	MESF[e]	Phase II
Corn	52.35	47.06	41.91	47.06	42.30	57.45
SBM (48.5%)	--	--	--	--	--	22.63
Soy protein[f]	9.09	14.26	19.61	14.26	19.09	--
Dried whey	20.00	20.00	20.00	20.00	20.00	10.00
Soybean oil	5.00	5.00	5.00	5.00	5.00	3.00
SD porcine plasma	7.50	7.50	7.50	7.50	7.50	--
Monocal phosphate	1.96	1.93	1.85	1.93	1.91	1.95
SD blood meal	1.75	1.75	1.75	1.75	1.75	2.50
Limestone	.73	.80	.68	.80	.76	.82
Vitamin premix	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15
L-lysine HCl	.012	.10	.10	.10	1.00	.10
DL-methionine	.075	.075	.075	.075	.075	.08
Copper sulfate	.012	.135	.135	.135	.138	.08
L-cystine	.075	--	--	--	--	--
Antibiotic[g]	1.00	1.00	1.00	1.00	1.00	1.00

[a] All phase I diets were formulated to contain 1.6% lysine, .44% methionine, .90% Ca, and .80% P; the phase II diet contained 1.25% lysine and .36% methionine.
[b] MESPC = moist extruded soy protein concentrate.
[c] SBM = soybean meal (48.5%).
[d] SPC = soy protein concentrate.
[e] MESF = moist extruded soy flour.
[f] Column heading represents product used.
[g] Provided 50g/ton carbadox.

Table 2. Performance of Pigs Receiving Different Soy Sources during Phase I[a]

Item	Casein	MESPC[b]	SBM[c]	SPC[d]	MESF[e]	CV
d 0 to 14						
ADG	.65	.65	.57	.59	.58	16.1
ADFI	.66[f,g]	.68[f]	.60[g]	.61[f,g]	.59[g]	13.9
F/G	1.03	1.04	1.06	1.04	1.02	6.0
d 14 to 28						
ADG	1.05[f,g,h]	1.10[f]	1.08[f,g]	1.02[g,h]	1.00[h]	7.37
ADFI	1.64[g]	1.82[f]	1.65[g]	1.65[g]	1.58[g]	8.00
F/G	1.58[f,g,h]	1.65[f]	1.53[h]	1.62[f,g]	1.58[f,g,h]	5.01
d 0 to 28						
ADG	.85[f,g]	.88[f]	.83[f,g]	.81[g]	.79[g]	9.4
ADFI	1.15[f]	1.25[g]	1.12[f]	1.13[f]	1.08[f]	9.0
F/G	1.37[f,h]	1.42[g]	1.37[h,f]	1.41[f,g,h]	1.37[f,g,h]	3.5
Ingredient cost/ton, $[i,j]	935.00	641.00	515.00	636.00	629.00	
Cost/lb of gain, $						
d 0 to 14	.48	.33	.27	.33	.32	
d 14 to 28	.18	.18	.17	.18	.18	
d 0 to 28	.29	.26	.19	.24	.22	

[a] Two hundred and ninety five weanling pigs were used (initially 13.3 lb and 21 d of age), 6 or 13 pigs/pen with 7 pens per treatment.

[b] MESPC = moist extruded soy protein concentrate.

[c] SBM = soybean meal (48.5%).

[d] SPC = soy protein concentrate.

[e] MESF = moist extruded soy flour.

[f,g,h] Means in row not bearing a common superscript differ (P<.10).

[i] Ingredient cost used were corn, $.04 per lb; casein, $2.51 per lb; MESPC, $.57 per lb; SBM, $.107 per lb; SPC, $.53 per lb; MESF, $.38 per lb.

[j] Phase II diet cost was $224.

EFFECTS OF WHEAT GLUTEN AND PLASMA PROTEIN ON GROWTH PERFORMANCE AND DIGESTIBILITY OF NUTRIENTS IN NURSERY PIGS

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Summary

An experiment was conducted to determine the nutritional value of wheat gluten and spray-dried porcine plasma in diets for weanling pigs. For the experiment, 120 pigs (14 lb avg initial body wt) were used in a 35-d growth assay. Treatments fed from d 0 to 14 postweaning were: 1) a dried skim milk-dried whey-soybean meal-based control; and 2, 3, and 4) spray-dried wheat gluten, spray-dried porcine plasma, and a blend of the wheat gluten and porcine plasma used to replace dried skim milk on a protein basis. All pigs were fed the same corn-soybean meal-dried whey-based diet from d 14 to 35. For d 0 to 14, pigs fed porcine plasma protein had greater average daily gain and average daily feed intake than pigs fed wheat gluten. However, for d 14 to 21 (i.e., during the transition period to the phase II diet), pigs fed diets with wheat gluten had the greatest feed intake and rate of gain compared with pigs fed other protein sources during phase I. Overall, pigs fed diets with wheat gluten and(or) plasma protein had greater rates and efficiencies of gain than pigs fed dried skim milk. The results indicate that spray-dried porcine plasma protein improves growth rate for the initial postweaning phase; however, feeding spray-dried wheat gluten during phase I results in improved growth performance during the transition to a phase II diet.

(Key Words: Wheat Gluten, Plasma Protein, Growth, Digestibility, Nursery.)

Introduction

Nutritional programs for weanling pigs have evolved greatly in the last decade, largely in response to the use of high quality sources of ingredients such as human-grade milk products. Use of milk products has improved rates and efficiencies of gain in weanling pigs, but the demand for milk products as human food often makes their use in diets for pigs cost prohibitive. Therefore, identifying less expensive protein sources that can be used in diets for weanling pigs is a major focus of research here at Kansas State University.

Spray-dried wheat gluten (WG) is wheat protein (70 to 80% total CP), with some carbohydrates, lipids, and fiber remaining when the starch is removed from wheat kernels. Previously reported experiments here at KSU indicated improved growth performance in nursery pigs when WG was used to replace the dried skim milk (DSM) in phase I diets (i.e., for 7 to 14 d postweaning). However, this response resulted from a carryover effect into phase II rather than an immediate response during phase I. In contrast, spray-dried porcine plasma protein (SDPP) improves growth performance of nursery pigs when added to phase I diets, but much of the benefit is lost unless SDPP or a high quality spray-dried blood meal is fed during phase II. Thus, questions remain as to the possible complementary effects from improved growth performance in phase I by adding SDPP and improved growth performance in phase II from the carry-over effect of WG fed during phase I. The experiment reported herein was conducted to determine the benefits of feeding WG and(or) SDPP in phase I on growth performance and nutrient digestibility of pigs for the entire nursery period.

Procedures

One hundred and twenty weanling pigs, averaging 21 d of age and 14 lb body weight, were used in a 35-d growth assay to evaluate WG and SDPP as replacements for DSM in phase I nursery diets. The pigs were randomly allotted to five treatments based on body weight, sex, and ancestry. Treatments were: 1) a DSM-dried whey-soybean meal-based control; 2) WG and lactose to replace the DSM; 3) SDPP and lactose to replace the DSM; and 4) a WG-SDPP blend and lactose to replace the DSM. The WG, SDPP, and WG-SDPP blend were added to supply the same amount of CP supplied by the DSM in the control diet, with lactose added so all diets had 25% lactose. The WG-SDPP blend had 50% of the CP from WG and 50% from SDPP. The diets (Table 1) were fed from d 0 to 14 postweaning (phase I) in pelleted form. All pigs were fed the same pelleted corn-soybean meal-dried whey-based diet from d 14 to 35 (phase II).

The pigs were housed in 4 ft × 5 ft pens with wire-mesh flooring. Room temperatures were 90, 87, 84, 80, and 75°F for wk 1 to 5, respectively. Each pen had a self-feeder and nipple water to allow ad libitum consumption of feed and water. There were six pigs per pen and five pens per treatment. Pigs and feeders were weighed weekly to allow calculation of average daily gain (ADG), average daily feed intake (ADFI), and feed/gain (F/G). Chromic oxide (.2%) was included in the diets as an indigestible marker. On d 10 and 20 (i.e., before and after the change to the phase II diet) fecal samples were collected from four pigs per pen by rectal massage. The fecal samples were dried, pooled, and ground for determination of dry matter (DM), nitrogen (N), and chromium concentrations. Apparent digestibilities of DM and N were calculated using the indirect ratio procedure with chromic oxide as the marker.

The experiment was a randomized complete block with initial body weight as the blocking criterion. Pen was the experimental unit. Response criteria were ADG, ADFI, F/G, and apparent digestibilities of DM and N. Treatment means were separated using the orthogonal contrasts: 1) DSM vs the other protein sources; 2) WG and SDPP vs the WG-SDPP blend; and 3) WG vs SDPP.

Results and Discussion

Crude protein concentrations of the protein sources were 33%, 74%, and 72% for DSM, WG, and SDPP, respectively (Table 2). However, in formulations of cereal grain-based diets for nonruminants, the lysine concentration is of greater importance than CP. When expressed as a percent of CP, DSM and SDPP had 7.5 and 9.0% lysine, but WG had only 1.8% lysine. Thus, when using WG in diets for nursery pigs, careful attention must be given to ensure that diets are adequate for the essential amino acids rather than crude protein per se.

During phase I, pigs fed SDPP had greater ADG (P<.03) and ADFI (P<.04) compared to pigs fed WG, but pigs fed the various protein sources had similar F/G (Table 3). Comparison of pigs fed the diet with SDPP to those fed the diet with WG also indicated 6% and 8% improvements in digestibilities of DM (P<.001) and N (P<.02), respectively, on d 10 of the experiment.

For the first 7 d of phase II (d 14 to 21), there were carryover effects of phase I treatments, with pigs fed WG in phase I having greater ADG (P<.09) and ADFI (P<.02) compared to pigs fed diets with SDPP. Pigs fed diets with WG and SDPP during phase I had greater ADFI (P<.04) compared to pigs fed the WG-SDPP blend. Nutrient digestibilities were not statistically different at d 20 for the treatment groups.

For d 14 to 35, pigs fed DSM in phase I had the poorest ADG (P<.08) and F/G (P<.05) compared to those fed the other diets. Pigs fed WG in phase I had greater ADFI (P<.07) than pigs fed SDPP. Overall (d 0 to 35), pigs fed the diet with DSM during d 0 to 14 had lower ADG (P<.05) and worse F/G (P<.01) than pigs fed the other protein sources. Pigs fed the WG-SDPP blend during phase I had numerically the greatest ADG of any treatment (7% greater than any other treatment); however, the effect was not statistically significant (P<.15).

In conclusion, using WG, SDPP, or a WG-SDPP blend in phase I diets with a common whey-soybean meal-corn-based phase II diet for nursery pigs improved overall ADG and F/G when compared to a phase I diet with DSM. These results seem to result from a greatly improved feed intake for weaned pigs fed SDPP during phase I and from a carryover effect of WG into the transition to a phase II diet. Further studies are needed to quantify additional benefits that might be achieved by feeding WG-SDPP blends and to determine the effects of feeding WG, SDPP, and a WG-SDPP blend for the entire nursery phase.

Table 1. Diet Composition

	Phase I Protein Sources[ab]				Phase II
Item, %	DSM	WG	SDPP	WG-SDPP	Diet[c]
Corn	34.22	33.59	33.86	33.83	45.11
Dried whey	20.00	20.00	20.00	20.00	20.00
DSM	20.00	—	—	—	—
WG	—	8.88	—	4.48	—
SDPP	—	—	9.25	4.63	—
Lactose	—	10.00	10.00	10.00	—
Soybean meal (48% CP)	19.64	19.64	19.64	19.64	28.81
Soybean oil	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate	1.19	2.12	2.21	2.16	1.27
Limestone	.28	.40	.34	.37	.51
Vitamin premix[d]	.25	.25	.25	.25	.25
Trace mineral premix[d]	.15	.15	.15	.15	.15
Salt	—	.20	—	—	.20
Copper sulfate	.10	.10	.10	.10	.10
Chromic oxide	.10	.10	.10	.10	.10
Lysine-HCl	.07	.57	—	.29	—
DL-methionine	—	—	.10	—	—
Antibiotic[e]	1.00	1.00	1.00	1.00	.50
Total	100	100	100	100	100

[a] The phase I diets (d 0 to 14) were formulated to 22% CP, 1.4% lysine, 25% lactose, .9% Ca, and .8% P.

[b] DSM = dried skim milk, WG = spray-dried wheat gluten, and SDPP = spray-dried porcine plasma.

[c] The phase II diet (d 14 to 35) was formulated to 20% CP, 1.2% lysine, 15% lactose, .8% Ca, and .7% P.

[d] KSU vitamin and trace mineral premixes.

[e] Antibiotic supplied 100, 100, and 50 g/ton of chlortetracycline, sulfathiazole, and penicillin, respectively.

Table 2. Chemical Composition of Protein Sources[a]

Item	DSM[b]	WG[c]	SDPP[d]
Crude protein, %	33.3	74.3	72.0
Amino acids, % of sample			
Arginine	1.2	2.6	4.3
Histidine	.9	1.4	2.4
Isoleucine	2.2	2.2	2.8
Leucine	3.3	4.7	7.3
Lysine	2.5	1.3	6.5
Methionine	.9	2.5	.7
Phenylalanine	1.6	3.4	4.1
Threonine	1.6	2.4	5.2
Tryptophan	.4	.6	1.5
Valine	2.3	2.2	4.7
Amino acids, % of CP			
Arginine	3.6	3.5	6.0
Histidine	2.7	1.9	3.3
Isoleucine	6.6	3.0	3.9
Leucine	9.9	6.3	10.1
Lysine	7.5	1.8	9.0
Methionine	2.7	3.4	1.0
Phenylalanine	4.8	4.6	5.7
Threonine	4.8	3.2	7.2
Tryptophan	1.2	.8	2.1
Valine	6.9	3.0	6.5

[a] DSM = dried skim milk, WG = spray-dried wheat gluten, and SDPP = spray-dried porcine plasma.

[b] Amino acid profile from NRC (1988).

[c] Amino acids analyzed using AOAC (1990) procedures.

[d] Amino acid profile courtesy of Merrick's, Inc.

Table 3. Performance of Pigs Fed Spray-Dried Wheat Gluten and Spray-Dried Plasma Protein during Phase I[a]

	Protein Sources[b]				Contrasts[cd]			
Item	DSM	WG	SDPP	WG-SDPP	1	2	3	SE
d 0 to 14								
ADG, lb	.79	.77	.87	.82	—	—	.03	.03
ADFI, lb	.82	.75	.86	.79	—	—	.04	.03
F/G	1.04	.97	.99	.96	—	—	—	.06
d 14 to 21								
ADG, lb	.64	.94	.68	.72	—	—	.09	.10
ADFI, lb	1.10	1.30	1.08	1.03	—	.04	.02	.06
F/G	1.72	1.38	1.59	1.43	—	—	—	.74
d 14 to 35								
ADG, lb	.89	1.02	.94	1.09	.08	.15	—	.06
ADFI, lb	1.59	1.63	1.52	1.63	—	—	.07	.04
F/G, lb	1.79	1.60	1.62	1.50	.05	—	—	.10
d 0 to 35								
ADG, lb	.85	.92	.91	.98	.05	.15	—	.03
ADFI, lb	1.28	1.28	1.25	1.29	—	—	—	.03
F/G, lb	1.51	1.39	1.37	1.32	.01	—	—	.05
Apparent digestibilities, %								
DM (d 10)	83.1	81.9	87.2	83.4	—	—	.001	.7
N (d 10)	81.0	77.7	84.3	79.8	—	—	.02	1.4
DM (d 20)	79.8	83.1	77.3	80.9	—	—	—	3.1
N (d 20)	74.6	76.6	73.4	74.1	—	—	—	4.8

[a] A total of 120 pigs (six pigs per pen and five pens per treatment) with an average initial body wt of 14 lb.

[b] DSM = dried skim milk, WG = spray-dried wheat gluten, and SDPP = spray-dried porcine plasma. Note that all pigs were fed a common diet (corn-SBM-dried whey-based) for phase II (d 14 to 35).

[c] Contrasts were: 1) DSM vs the other protein sources; 2) WG and SDPP vs the WG-SDPP blend; and 3) WG vs SDPP.

[d] Dash indicates P>.15.

COMPARISON OF CARBOHYDRATE SOURCES FOR THE EARLY-WEANED PIG[1]

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Summary

A total of 180 weanling pigs (initially 11.7 lb and 21 d of age) was used in a 35 d growth assay to compare various carbohydrate sources from d 0 to 14 postweaning in phase I. Pigs were allotted by weight and ancestry to one of five experimental diets with six pigs per pen and six replications per treatment. Pigs were fed one of five experimental diets from d 0 to 14 postweaning. The experimental carbohydrate sources compared were corn, oat flour, two modified potato starches, and lactose. All pigs were then fed a common phase II diet from d 14 to 35 postweaning. For the phase I period, pigs consuming the modified potato starch 1 diet had higher average daily gain (ADG) and average daily feed intake (ADFI) than pigs consuming the corn or oat flour diets. Pigs consuming the modified potato starch 1 diet had numerically higher ADG and ADFI than pigs fed the other four diets. The performance of pigs consuming the modified potato starch 1 diets warrants further investigation. Currently, the hygroscopic nature of modified potato starches prohibits regular application in starter pig diets, because it causes problems in feed manufacturing and ingredient handling. Pigs consuming the lactose diets had higher ADG than the pigs consuming the corn diet. During the phase II (d 14 to 35 postweaning) and cumulative (d 0 to 35 postweaning) periods, no differences occurred in growth performance. Thus, economics indicate no additional inclusion of lactose in the phase I diet above 18% (25% dried edible grade whey). No differences occurred in performance for any phase of the experiment between the pigs consuming the corn or oat flour diets. In conclusion, oat flour does not appear to be a better carbohydrate source than corn in the phase I nursery diet.

(Key Words: Starter, Carbohydrate.)

Introduction

Recent research at Kansas State University indicates that increasing the level of lactose from 7% to 23% in a spray-dried porcine plasma-based diet resulted in a linear improvement in growth performance. Several other carbohydrate sources have been used by the feed industry to decrease the amount of corn in the phase I diet. The main purpose of the alternative carbohydrate sources is to provide the young pig with a more digestible carbohydrate source than corn. Carbohydrate sources compared in this experiment included corn, oat flour, two modified potato starches, and lactose. Oat flour is used as a food ingredient in the human food industry. Modified potato starch 1 was treated to break the carbohydrate molecules into individual glucose molecules and then spray-dried. Modified potato starch 2 was treated to break the starch molecules into glucose chains of

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[1] Appreciation is expressed to AVEBE America Inc. for the donation of modified potato starches.

intermediate length and spray-dried. These intermediate glucose chains are composed of primarily malto dextran. Lactose is a very simple and highly digestible sugar made up of one glucose and one galactose molecule bonded together. This experiment was designed to compare corn, oat flour, potato starch 1, modified potato starch 2, and lactose as carbohydrate sources in the phase I diet for the early weaned pig.

Procedures

A total of 180 weanling pigs (initially 11.7 lb and 21 d of age) was used in a 35 d growth assay. Pigs were allotted by weight and ancestry to one of five experimental treatments with six pigs per pen and six replications per treatment. Pigs were fed the five experimental diets from d 0 to 14 postweaning. The phase I diets contained 7.5% spray-dried porcine plasma, 1.75% spray-dried blood meal, and 25% edible grade dried whey (Table 1.). These diets were formulated to contain 1.6% lysine, .44% methionine, .9% calcium, and .8% phosphorus. Soybean meal level was held constant in all phase I diets. The various carbohydrate sources were substituted on an equal lysine basis using a combination of casein and L-lysine HCl. The five diet carbohydrate inclusion levels were as follows: 1) 36.5% ground corn (corn), 2) 36.5% oat flour (oat flour), 3) 12% modified potato starch 1 and 23.9% ground corn (potato starch 1), 4) 12% modified potato starch 2 and 23.9% ground corn (potato starch 2), and 5) 12% lactose and 23.9% ground corn (lactose). All pigs were fed a common phase II diet from d 14 to 35 postweaning. This diet contained 10% edible grade dried whey and 2.5% spray-dried blood meal. The phase II diet was formulated to contain 1.25% lysine, .36% methionine, .9% calcium, and .8% phosphorus. All diets were fed in meal form. Pigs were housed in an environmentally controlled nursery with metal flooring and were allowed ad libitum access to feed and water. Pigs were weighed and feed disappearance was measured on d 7, 14, 21, 28, and 35 postweaning to determined ADG, ADFI, and feed efficiency (F/G).

Results and Discussion

For the phase I period (0 to 14 d postweaning), pigs consuming modified potato starch 1 diet had higher ADG ($P<.05$) and ADFI ($P<.05$) than pigs consuming the corn or oat-flour based diets. Pigs consuming the modified potato starch 1 diet had numerically higher ADG and ADFI than pigs fed the other four diets. As a result, pigs fed the modified potato starch 1 diet were heavier ($P<.05$) on d 14 postweaning than pigs consuming the corn or oat flour diets. Pigs consuming the lactose diet had higher ADG ($P<.05$) than pigs consuming the corn diet. During phase II, no differences occurred in growth performance when pigs were fed a common diet. Also, no difference was seen in pig weights on d 35 postweaning. This is the result of a decrease in ADG for the 14 to 21 d postweaning period with the two modified potato starches and lactose diets compared to the corn and oat flour diets.

The performance of pigs consuming the modified potato starch 1 warrants further investigation. Currently, the hygroscopic nature of modified potato starches prohibits regular application in starter pig diets because it causes major problems in feed manufacturing and ingredient handling. Although added lactose resulted in higher ADG than the corn diet for pigs in phase I, no difference in performance occurred for the overall period. Thus, economics indicate no additional inclusion of lactose in the phase I diet above 18% (25% dried edible grade whey).

No differences in performance were seen for any phase of the experiment between the pigs consuming the corn or oat flour diets. Many companies in the commercial feed industry advocate no inclusion of corn in the phase I diet. The alternative ingredients substituted for corn usually increase the cost of the diet. The results of this trial support the inclusion of corn in the phase I diet on the basis of economics and performance. In conclusion, oat flour does not appear to be a better carbohydrate source than corn in the phase I nursery diet.

Table 1. Diet Composition[a]

	Carbohydrate Source - Phase I					
Ingredient	Corn	Oat	Potato Starch 1	Potato Starch 2	Lactose	Phase II
Corn	36.51	--	23.92	23.92	23.92	58.76
Oat flour	--	36.56	--	--	--	--
Potato starch 1	--	--	12.00	--	--	--
Potato starch 2	--	--	--	12.00	--	--
Lactose	--	--	--	--	12.00	--
Dried whey	25.00	25.00	25.00	25.00	25.00	10.00
Soybean meal (48.5% CP)	19.18	19.18	19.18	19.18	19.18	21.26
Spray-dried porcine plasma	7.50	7.50	7.50	7.50	7.50	--
Soybean oil	6.00	6.00	6.00	6.00	6.00	3.00
Spray-dried blood meal	1.75	1.75	1.75	1.75	1.75	2.50
Monocalcium phosphate (21% P)	1.75	1.89	1.90	1.90	1.90	1.97
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00	1.00
Casein	--	--	.51	.51	.51	--
Limestone	.62	.54	.55	.55	.55	.83
Vitamin premix	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15
DL-methionine	.136	.106	.145	.145	.145	.05
Copper sulfate	.075	.075	.075	.075	.075	.075
L-lysine HCl	.074	--	.072	.072	.072	.150
Total	100	100	100	100	100	100

[a] All carbohydrate source diets were formulated to contain 1.6% lysine and .46% methionine. The phase II diet was formulated to contain 1.25% lysine and .36% methionine. All diets were formulated to contain .9% calcium and .8% phosphorus.

[b] To provide 150 g/ton of apramycin in Phase I and 50 g/ton carbadox in Phase II.

Table 2. Influence of Carbohydrate Source in Phase I on Growth Performance[a]

Item	Corn	Oat	Pot 1	Pot 2	Lactose	CV
d 0 to 14						
ADG, lb[b]	.69^{x}	.72^{xy}	.82^{z}	.75^{xyz}	.77^{yz}	8.3
ADFI, lb[b]	.89^{x}	.88^{x}	1.00^{y}	.91^{xy}	.97^{xy}	8.7
F/G	1.34	1.21	1.24	1.21	1.31	7.6
d 14 to 35						
ADG, lb	1.08	1.11	1.14	1.11	1.06	8.1
ADFI, lb	2.26	2.31	2.28	2.19	2.15	4.9
F/G	2.13	2.05	1.99	1.98	2.10	7.1
d 0 to 35						
ADG, lb	.92	.95	1.01	.96	.94	6.8
ADFI, lb	1.73	1.74	1.76	1.68	1.68	4.7
F/G	1.88	1.83	1.74	1.74	1.84	6.2

[a] One hundred sixty weanling pigs were used (initially 11.7 lb and 21 d of age), six pigs per pen, six pens per treatment. Experimental diets were fed from d 0 to 14 postweaning, and all pigs were fed a common phase II diet from d 14 to 35 postweaning.

[b] Means lacking a common superscript differ (P<.05).

Table 3. Influence of Carbohydrate Source in Phase I on Pig Weights[a]

Item, lb	Corn	Oat	Pot 1	Pot 2	Lactose	CV
d 0	11.7	11.7	11.7	11.7	11.7	--
d 14[b]	21.4^{x}	21.8^{xy}	23.2^{z}	22.2^{xyz}	22.6^{yz}	3.9
d 35	44.1	45.0	47.1	45.5	44.8	5.0

[a] One hundred sixty weanling pigs were used (initially 11.7 lb and 21 d of age), six pigs per pen, six pens per treatment. Experimental diets were fed from d 0 to 14 postweaning, and all pigs were fed a common phase II diet from d 14 to 35 postweaning.

[b] Means lacking a common superscript differ (P<.05).

PELLET QUALITY AFFECTS GROWTH PERFORMANCE OF NURSERY AND FINISHING PIGS

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Summary

Two experiments were conducted to determine the effects of diet form (meal vs pellet) and amount of fines in pelleted feed on growth performance of nursery and finishing pigs. One hundred twenty-six weanling pigs, with an average initial body wt of 12.5 lb, were used in the 35-d nursery experiment. The same phase I diet (pelleted) was fed to all pigs for 7 d, then the pigs were switched to phase II diet treatments (d 7 to 35 postweaning). Treatments were the same phase II diet fed as: 1) meal; 2) screened pellets (fines removed); and 3) the screened pellets with 25% added fines. From d 7 to 21, average daily gain (ADG) tended to be greater for pigs fed pellets, and feed/gain (F/G) was improved by 14% when pigs were fed pelleted diets compared with those fed the meal diet. Also, pigs fed the screened pellets had a 7% improvement in F/G compared to pigs fed the pelleted diet with 25% fines. From d 7 to 35, pigs fed pelleted diets were 9% more efficient than pigs fed the meal diet. Also, pigs fed the pelleted diet with 25% added fines had 2.6% poorer F/G than pigs fed the diet with screened pellets. In the finishing experiment, 80 gilts (average initial body wt of 118 lb) were used to evaluate the effects of diet form and pellet fines on growth performance. Treatments were a common finishing diet fed as: 1) meal; 2) screened pellets; 3) pellets with 20% fines; 4) pellets with 40% fines; and 5) pellets with 60% fines. Pigs fed the meal diet or the diet with 60% fines tended to have decreased ADG compared to pigs fed the other pelleted diets. Pigs fed screened pellets had a 4.7% improvement in F/G compared with those fed the meal diet. However, increasing the amount of fines in the screened pellets diet resulted in a linear trend for poorer F/G. These results suggest that pelleting diets improved growth performance in nursery and finishing pigs; however, increasing amounts of pellet fines reduced the advantage of feeding a pelleted diet.

(Key Words: Nursery, Finishing, Pellets, Process.)

Introduction

In the 1992 KSU Swine Day Report (page 122), Wondra et al. reported that pelleting diets for finishing pigs improved nutrient digestibility and growth performance. However, our experience indicates that improperly pelleted feed, with a significant amount of fines, results in greater feed wastage, increased requirements for feeder management, reduced palatability, and decreased feed intake. Interestingly, controlled research projects have not been reported that determine if, or how much, the presence of fines in pelleted diets affects growth performance of pigs. Reported herein are experiments conducted to determine the effects of pellet fines on growth performance of nursery and finishing pigs.

Procedures

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Nursery Experiment. One hundred twenty six weanling pigs, with an initial body wt of 12.5 lb, were used in a 35-d growth assay to evaluate the effects of pellet fines on growth performance. The pigs were blocked by weight and randomly allotted to pens based on sex and ancestry. There were six pigs per pen (three barrows and three gilts) and seven pens per treatment. The pigs were fed the same pelleted phase I diet (Table 1) from d 0 to 7 postweaning and then switched to the phase II dietary treatments. The phase I diet was formulated to contain 1.5% lysine, .9% Ca, and .8% P. The phase II diet was formulated to contain 1.25% lysine, .9% Ca, and .8% P, and fed from d 7 to 35 postweaning. Treatments were the phase II diet fed as: 1) meal; 2) screened pellets (fines removed); and 3) the screened pellets with 25% added fines. Pelleted feed was processed with a California Pellet Mill 1000 Series Master H.D. Model® equipped with a 5/32 in × 1 1/2 in (hole diameter vs die thickness) die for the phase I diet and a 5/32 in × 2 in die for the phase II diet. Conditioning temperatures were 145°F for the phase I diet and 150°F for the phase II diet. Fines were made by passing the screened pellets through crumblizing rolls. Fines were characterized as material that would pass through a Tyler #6 sieve (3,360 µm openings).

The pigs were housed in 4 ft × 5 ft pens with wire-mesh flooring. Each pen had a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. Fines were removed from the feeders on a weekly basis and weighed to allow calculation of daily fines accumulation. Pigs and feeders were weighed on d 7, 21, and 35 for calculation of ADG, ADFI, and F/G. Data were analyzed as a randomized complete block design with pen as the experimental unit. Contrasts used to separate means were: 1) meal vs pelleted diets and 2) screened pellets vs 25% added fines.

Finishing Experiment. Eighty gilts, with an average initial body wt of 118 lb, were used to compare the response to a meal diet vs pelleted diets with different amounts of fines. The pigs were blocked by weight and allotted to pens based on ancestry. There were two pigs per pen and eight pens per treatment. Treatments were a common finishing diet fed as: 1) meal; 2) screened pellets; 3) pellets with 20% fines; 4) pellets with 40% fines; and 5) pellets with 60% fines.

The diet contained corn and soybean meal with 3% added soybean oil and was formulated to .70% lysine, .65% Ca, and .55% P (Table 1). Pellets were processed with the pellet mill used in the nursery trial, but equipped with a 3/16 in × 1 1/2 in die. The conditioning temperature was 170°F. Fines were made by mechanically handling the pellets in a Forberg® mixer until the proper amount of fines was achieved. Fines were characterized as material that would pass through a Tyler #5 sieve (4,000 µm openings).

The pigs were housed in 5 ft × 5 ft pens with slatted concrete flooring. Each pen had a single-hole self-feeder and nipple waterer to allow ad libitum consumption of feed and water. The pigs were weighed at initiation and termination of the growth assay to allow calculation of ADG, ADFI, and F/G. Data were analyzed as a randomized complete block design with pen as the experimental unit. Contrast used to separate means were: 1) meal vs pellets, 2, 3, and 4) linear, quadratic, and cubic response to the amount of fines.

Results and Discussion

Nursery Experiment. The pelleted diet had a 97% pellet durability index (PDI) in phase I and a 94% PDI in phase II; therefore, the nursery pigs were fed high quality pellets that were above industry standards. The pigs fed the common phase I diet had similar growth performance (ADG, ADFI, and F/G were .62 lb, .64 lb, and 1.03, respectively). However, during the transition to the phase II diet (d 7 to 21), pigs fed the pelleted diets had numerically greater ADG (10% improvement) and significantly greater (P<.01) F/G (14% improvement) compared to pigs fed the meal diet (Table 2). Improved F/G was also observed for the overall experiment when pigs were fed pellets vs the meal diet (P<.01) and screened pellets vs pellets with 25% added fines (P<.07). Also 2.5 times more fines (P<.01) were removed weekly from the feeders of pigs fed the diet with 25% fines compared to the feeders of pigs fed the screened pellets.

Finishing Experiment. The pelleted diet had an average PDI of 71% before mechanical handling. A pellet durability index of 70% for simple corn-soybean meal-based formulas with 3% added fat would be considered acceptable by industry standards. Pigs fed the screened pellets had 3% greater ADG and a 5% improvement in F/G compared with pigs fed the meal diet (Table 3). The addition of fines did not affect ADG, but F/G became poorer (P<.10) as the amount of fines in the diet increased. Therefore, the improvement in F/G for pigs fed pelleted feed was lost as the amount of fines increased.

These experiments demonstrate that growth performance of nursery and finishing pigs is improved by pelleting. However, poor quality pellets, as indicated by accumulation of fines, can negate any benefits in rate and(or) efficiency of gain. Further research is needed to define the amount of fines that is tolerated by pigs, but at present, our data indicate that as little as 20 to 25% fines significantly reduces the benefits of pelleted starter and finishing diets for pigs.

Table 1. Diet Composition, %

	Nursery Experiment		
Ingredient	Phase I[a]	Phase II[b]	Finishing Experiment[c]
Corn	37.07	53.35	79.64
Soybean meal (48% CP)	16.00	25.00	14.45
Spray-dried porcine plasma	7.50	—	—
Spray-dried blood meal	2.50	2.50	—
Dried whey	20.00	10.00	—
Lactose	10.00	—	—
Soybean oil	3.00	5.00	3.00
Monocalcium phosphate	2.00	1.94	1.12
Limestone	.74	.96	1.05
Lysine-HCl	.10	.07	.06
DL-methionine	.11	—	—
Salt	—	.20	.30
Vitamin premix	.25	.25	.17
Trace mineral premix	.15	.15	.11
Copper sulfate	.08	.08	—
Antibiotic	.50[d]	.50[d]	.10[e]

[a] Phase I diets were formulated to 1.5% lysine, .40% methionine, .90% Ca, and .80% P.
[b] Phase II diets were formulated to 1.25% lysine, .32% methionine, .90% Ca, and .80% P.
[c] Diets were formulated to .7% lysine, .65% Ca, and .55% P.
[d] Provided 100 g/ton chlortetracycline, 100 g/ton sulfathiazole, and 50 g/ton penicillin.
[e] Provided 100 g/ton chlortetracycline.

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

Item	Meal	Screened Pellets	Screened Pellets & 25% Fines	SE
d 7 to 21				
ADG, lb	.71	.80	.76	.04
ADFI, lb	1.23	1.15	1.18	.05
F/G[b]	1.73	1.44	1.55	.03
d 7 to 35				
ADG, lb	1.03	1.07	1.08	.03
ADFI, lb	1.72	1.61	1.67	.05
F/G[c]	1.67	1.50	1.54	.02
Daily fines accumulation, lb/d[d]	—	.13	.32	.02

[a] A total of 126 weanling pigs with an average initial body wt of 12.5 lb (6 pigs/pen and 7 pens/treatment).

[b] Meal vs pelleted (P<.01); screened pellets vs 25% added fines (P<.05).

[c] Meal vs pelleted (P<.01); screened pellets vs 25% added fines (P<.07).

[d] Screened pellets vs 25% added fines (P<.01).

Table 3. Effects of Pellet Fines on Growth Performance of Finishing Pigs[a]

			Percentage Fines			
Item	Meal	Screened Pellets	20	40	60	SE
ADG, lb	2.05	2.11	2.11	2.12	2.07	.05
ADFI, lb	5.69	5.59	5.86	5.87	5.84	.19
F/G[b]	2.78	2.65	2.78	2.77	2.82	.07

[a] A total of 80 pigs with an average initial body wt of 118 lb (2 pigs/pen and 8 pens/treatment).

[b] Linear effect of fines (P<.10).

COMPARISON OF FEED-GRADE ANTIBIOTICS IN STARTER DIETS CONTAINING SPRAY-DRIED BLOOD PRODUCTS[1]

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Summary

A total of 240 pigs (initially 11.6 lb and 19 d of age) was used to compare four different feed-grade antibiotics or antibiotic combinations in phase I (d 0 to 14 postweaning) and phase II (d 14 to 28 postweaning) starter pig diets. Apramycin and carbadox were compared in the phase I diet. Combinations of tylosin/sulfamethazine and neomycin sulfate/oxytetracycline were compared in the phase II diet. No differences occurred in pig performance for the phase I and phase II periods between the feed-grade antibiotics compared in this growth assay. Therefore, determination of appropriate feed-grade antibiotic inclusion will depend on 1) economics, 2) disease profile of the herd, and 3) growth response within a particular producer's herd.

(Key Words: Starter, Performance, Antibiotic.)

Introduction

Numerous growth-promoting antibiotics are available for addition to starter pig diets. Producers are continually faced with the challenge of deciding which feed-grade antibiotics are appropriate for their swine business. This decision often is based on nontechnical information and testimonials rather than research data. Therefore, this trial had three objectives 1) to compare apramycin and carbadox inclusion in phase I (d 0 to 14 postweaning), 2) to compare a tylosin/sulfathiazole combination and a neomycin/oxytetracycline combination in phase II (d 14 to 28 postweaning), and 3) to determine the appropriate sequence of feed grade antibiotic usage in phase I and phase II starter pig diets containing spray-dried blood products.

Procedures

A total of 240 pigs (initially 11.6 lb and 19 d of age) was used in a 28 d growth trial. The trial consisted of two phases. Phase I was from d 0 to 14 postweaning, and phase II was from d 14 to 28 postweaning. Pigs were allotted by weight and placed in 4 ft by 6 ft pens (10 pigs per pen) in an environmentally controlled nursery facility on a commercial farm in northeast Kansas. Each pen contained two nipple waterers, and pigs were allowed ad libitum access to feed and water. Pigs were assigned to one of four treatments based on the sequence of feed-grade antibiotic inclusion. Either 150 g/ton apramycin or 50 g/ton carbadox were included in the phase I diet and a combination of either 100 g/ton tylosin/100 g/ton sulfamethazine (Tylan-sulfa) or 100 g/ton neomycin sulfate/100 g/ton oxytetracycline (Neo-terra) in the phase II diet. Phase I diets were formulated to contain 1.5% lysine, .42% methionine, .9% calcium, and .8% phosphorus. The phase I diets contained 7.5% spray-dried porcine plasma, 1.75% spray-dried blood

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meal, and 20% dried whey. Phase II diets were formulated to contain 1.25% lysine, .34% methionine, .9% calcium, and .8% phosphorus. The phase II diets contained 10% dried whey and 2.5% spray-dried blood meal. Phase I diets were fed in pellet form, and phase II diets were fed in meal form. Pigs and feeders were weighed on d 7, 14, 21, and 28 to evaluate ADG, ADFI, and F/G.

Results and Discussion

No mortality occurred during the 28 d growth period. During phase I, no differences occurred in ADG, ADFI, and F/G between pigs fed apramycin or carbadox (Table 3). Phase I feed-grade antibiotic did not influence phase II performance, and no interactions occurred between feed-grade antibiotic sources fed during phases I and II (Table 5). In addition, no differences occurred in performances between pigs fed tylosin/sulfamethazine or neomycin/oxytetracycline in phase II (Table 4). Because of the similar growth performance, results of this trial indicate that the choice between the feed-grade antibiotics used in this study will depend on economics and risk or perceived risk of tissue residue. In conclusion, this growth assay provides information to swine producers to aid in the selection of feed-grade antibiotics in starter pig diets.

Table 1. Diet Composition

Item	Phase I	Phase II
Corn	45.29	59.26
Soybean meal, (48% CP)	16.13	21.26
Dried whey, edible grade	20.00	10.00
Spray-dried porcine plasma	7.50	—
Spray-dried blood meal	1.75	2.50
Soybean oil	5.00	3.00
Monocalcium phosphate	1.91	1.97
Limestone	.69	.83
Antibiotic	1.00	.50
Trace mineral premix	.15	.15
Vitamin premix	.25	.25
DL-methionine	.15	.05
L-lysine HCl	.10	.15
Copper sulfate	.075	.075
Total	100	100

Table 2. Feed-Grade Antibiotic Inclusion Levels

Item	Inclusion level, g/ton
Phase I	
Apramycin	150
Carbadox	50
Phase II	
Tylosin/sulfamethazine	100/100
Neomycin sulfate/oxytetracycline	100/100

Table 3. Phase I Performance (d 0 to 14 Postweaning)[ab]

Item	Apramycin	Carbadox	CV
ADG, lb	.57	.57	10.4
ADFI, lb	.64	.63	6.7
F/G	1.13	1.12	6.9

[a] Each value is the mean of 12 pens containing 10 pigs per pen. Pigs were initially 19 d of age and 11.6 lb.

[b] No significant treatment effects.

Table 4. Phase II Performance (d 14 to 28 Postweaning)[ab]

Item	Tylosin/ sulfamethazine	Neomycin sulfate/ oxytetracycline	CV
ADG, lb	.92	.93	8.7
ADFI, lb	1.45	1.44	4.9
F/G	1.58	1.57	6.4

[a] Each value is the mean of twelve pens containing 10 pigs per pen.

[b] No significant treatment effects.

Table 5. Growth Performance d 0 to 28 Postweaning[ab]

	Apramycin		Carbadox		
Item	Tylosin/ Sulfa[c]	Neo/ oxy[d]	Tylosin/ Sulfa	Neo/ oxy	CV
ADG, lb	.91	.90	.94	.96	8.7
ADFI, lb	1.47	1.41	1.43	1.46	4.9
F/G	1.63	1.59	1.53	1.54	6.4

[a] Diets were fed in two phases: Phase I (d 0 to 14 postweaning) and Phase II (d 14 to 28 postweaning). Each value is the mean of six pens containing 10 pigs per pen. Pigs were initially 19 d of age and 11.6 lb.

[b] No significant treatment effects.

[c] Tylosin/sulfamethazine.

[d] Neomycin sulfate/oxytetracycline.

EFFECT OF SPRAY-DRIED BLOOD MEAL IN THE PHASE III DIET

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Summary

A total of 216 weanling pigs was used to evaluate the use of spray-dried blood meal (SDBM) in the phase III diet for pigs weighing approximately 25 pounds. At weaning, pigs (initially 11.6 lb and 21 d of age) were allotted by weight, gender, and ancestry to the dietary treatments. There were six pigs per pen with six replications per treatment. Pigs were started on a common phase I diet containing 20% dried whey, 7.5% spray-dried porcine plasma, and 1.75% spray-dried blood meal. This diet was formulated to contain 1.5% lysine and .44% methionine. On d 7 postweaning all pigs were switched to a common phase II diet that contained 10% dried whey and 2.5% spray-dried blood meal and was formulated to contain 1.25% lysine and .35% methionine. On d 21 postweaning and when weight averaged approximately 25 pounds, pigs were switched to one of six diets, control or containing .5, 1.0, 1.5, 2.0, or 2.5% spray-dried blood meal, that were formulated to contain 1.15% lysine. Pigs were fed experimental diets from d 21 to 42 postweaning (phase III). During phase I, average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) were .54 lb, .61 lb, and 1.16, respectively. During phase II, ADG, ADFI, and F/G were .62 lb, 1.15 lb, and 1.90, respectively. On d 21, pigs weighed an average of 24 pounds when they were switched to the experimental diets. During phase III, linear ($P < .05$) depressions in ADG and F/G occurred with the addition of increasing levels of spray-dried blood meal in the diet. However, the reduction in performance was only evident at the 2 and 2.5% blood meal levels. Lower blood meal additions to the diet (< 2%) had no influence on pig performance. Similar to earlier research, our results indicate that complex protein sources are not required in the phase III diet for optimal pig performance.

(Key Words: Blood Meal, Starter Pigs, Performance.)

Introduction

Previous research conducted at Kansas State University has shown spray-dried blood meal to be an effective protein source to use in combination with spray-dried porcine plasma in the high nutrient density diet (phase I) and to include by itself in the phase II diet. Spray-dried blood meal is used primarily for its stimulatory effect on feed intake in the early-weaned pig to help improve starter pig performance in the early postweaning period. However, little research has been done investigating the use of spray-dried blood meal in diets for later stages of pig growth. Therefore, this experiment was conducted to investigate the effect of spray-dried blood meal on starter pig performance from 25 to 50 lb when they typically would be fed the phase III diet.

Procedures

A total of 216 pigs (initially 11.6 lb and 21 d of age) was used in a 42 d trial. Pigs were allotted by weight, gender, and ancestry and placed in pens containing six pigs/pen. All pigs were started on a common phase I diet containing 20% dried whey, 7.5% spray-dried porcine plasma, and 1.75% spray-dried blood meal and formulated to contain 1.5% lysine and .44% methionine. Pigs were fed this diet for the first 7 days postweaning, at which time they were switched to a common phase II diet that contained 10% dried whey and 2.5% spray-dried blood meal and formulated to 1.25% lysine and .35% methionine. Pigs were fed the phase II diet until they averaged approximately 25 pounds. Then pigs were switched to one of six dietary treatments. Experimental diets included a control and additions of .5, 1.0, 1.5, 2.0, or 2.5% spray-dried blood meal and were formulated to contain 1.15% lysine and .35% methionine. As shown by previous research conducted at Kansas State University, spray-dried blood meal is deficient in methionine. Therefore, DL-methionine was added as spray-dried blood level was increased to ensure that methionine was not limiting. Pigs received experimental diets from d 21 to 42 postweaning. Pigs and feeders were weighed on d 7, 14, 21, 28, 35, and 42 postweaning to evaluate ADG, ADFI, and F/G.

Results and Discussion

During phase I (d 0 to 7 postweaning), ADG, ADFI, and F/G were .54 lb, .61, and 1.16, respectively. During phase II (d 7 to 21 postweaning), ADG, ADFI, and F/G were .62 lb, 1.19 lb, and 1.90, respectively. When pigs were switched to experimental diets containing various levels of spray-dried blood meal, there were no significant differences in pig weights.

Increasing the blood meal level in the phase III diet (d 21 to 42 postweaning) caused linear ($P < .05$) depressions in ADG and F/G. Pigs receiving a diet containing no blood meal gained .08 lbs/day more than pigs receiving 2.5% blood meal. Feed efficiency ranged from 1.69 to 1.80 for pigs receiving the control and 2.5% spray-dried blood meal, respectively. However, the reduction in performance due to adding blood meal was only evident at the 2 and 2.5% blood meal levels. Lower blood meal additions (< 2%) had no influence on pig performance. Therefore, when the pig reaches approximately 25 pounds, spray-dried blood meal apparently is no longer required for maximal growth performance.

Previous research has demonstrated that spray dried blood meal is an excellent protein source for the phase I and II diets. These diets are essential to achieve high levels of growth performance immediately postweaning. However, once pigs are consuming adequate quantities of feed, simpler phase III starter diets are most economical. The results of this experiment support KSU recommendations of feeding complex starter diets during phase I and II and switching to a simple, corn-soybean meal diet for phase III.

Table 1. Diet Composition

Item, %	Phase I[a]	Phase II[b]
Corn	45.29	58.76
Soybean meal, 48.5% CP	16.13	21.26
Dried whey, edible grade	20.00	10.00
Spray-dried porcine plasma	7.50	-
Spray-dried blood meal	1.75	2.50
Soybean oil	5.00	3.00
Monocalcium phosphate, 21% P	1.91	1.97
Antibiotic[c]	1.00	1.00
Limestone	.69	.83
Vitamin premix	.25	.25
Trace mineral premix	.15	.15
DL-methionine	.15	.05
L-Lysine HCl	.10	.15
Copper sulfate	.075	.075
Total	100.00	100.00

[a] Diet was formulated to contain 1.5% lysine, .44% methionine, .9% Ca, and .8% P and was fed from d 0 to 7 postweaning.
[b] Diet was formulated to contain 1.25% lysine, .35% methionine, .9% Ca, and .8% P and was fed from d 7 to 21 postweaning.
[c] Provided 150 g/ton Apramycin in phase I and 50 g/ton Carbadox in phase II.

Table 2. Phase III Diet Composition[a]

	Spray-Dried Blood Meal, %					
Item, %	Control	.5	1.0	1.5	2.0	2.5
Corn	60.75	61.75	62.76	63.77	64.78	65.78
Soybean meal, 48.5% CP	31.99	30.45	28.91	27.37	25.83	24.30
Soybean oil	3.00	3.00	3.00	3.00	3.00	3.00
Spray-dried blood meal	-	.50	1.00	1.50	2.00	2.50
Monocalcium phosphate, 21% P	1.53	1.56	1.59	1.61	1.64	1.67
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	.89	.89	.89	.89	.89	.89
Salt	.35	.35	.35	.35	.35	.35
Vitamin premix	.25	.25	.25	.25	.25	.25
Trace mineral	.15	.15	.15	.15	.15	.15
Copper sulfate	.075	.075	.075	.075	.075	.075
DL-methionine	.014	.018	.022	.026	.031	.035
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a] Diets were formulated to contain 1.15% lysine and .35% methionine and were fed from d 21 to 42 postweaning.
[b] Provided 50 g/ton Carbadox.

Table 3. Influence of Spray-Dried Blood Meal in the Phase III Diet[a]

	Spray-Dried Blood Meal, %						
Item	Control	.5	1	1.5	2	2.5	CV, %
ADG, lb[b]	1.33	1.38	1.34	1.32	1.29	1.27	6.34
ADFI, lb	2.25	2.34	2.28	2.25	2.22	2.29	6.63
F/G[b]	1.69	1.70	1.70	1.69	1.72	1.80	4.64

[a] A total of 216 pigs with 6 pigs/pen and 6 pens/treatment (initially 24.0 lb and 42 d of age).
[b] Linear response ($P < .05$).

EFFECTS OF NURSERY DIETS ON GROWTH OF PIGS TO MARKET WEIGHT

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Summary

Two experiments were conducted to determine the effects of nutrient concentrations and complexity of ingredients used in nursery diets on growth performance to market weight. In Experiment 1, nursery regimens were: 1) simple ingredients/low lysine (corn-soybean meal-dried whey-based diet with 1.25% lysine for d 0 to 23 and a corn-soybean meal-based diet with 1.1% lysine for d 23 to 37) and 2) complex ingredients/high-lysine (blood products, lactose, and other specialty ingredients with 1.5% lysine for d 0 to 9 and 1.25% lysine for d 9 to 23, and a corn-soybean meal-based diet with 1.1% lysine for d 23 to 37). In general, feed intake and rate of gain were increased for pigs fed the complex/high-lysine regimen. This improved performance resulted in an average advantage of 5 lb/pig at the end of the nursery phase. For the growing-finishing phase, pigs from the simple/low-lysine and complex/high-lysine nursery regimens were assigned to either a 2-step (.8 and .6% lysine to 150 and 250 lb, respectively) or 4-step (.95, .8, .75, and .6% lysine to 100, 150, 200, and 250 lb, respectively) regimen and fed to a market wt of 250 lb. Pigs fed the 4-step regimen had greater rate of gain, but there was no complementary effect of the complex/high-lysine regimen in the nursery phase with the 4-step regimen in the growing-finishing phase. We should note, however, that there was also no compensatory response of the pigs fed the simple/low-lysine diet in the nursery phase when given either the 2-step or 4-step regimen during growing-finishing. The net result was that the 5 lb difference at the end of the nursery phase resulted in an additional 3.6 d required for pigs fed the simple/low-lysine regimen to reach a market wt of 250 lb.

In Experiment 2, the same diet regimens were used except that a third diet, with 1.5% lysine (resulting from adding wheat gluten and crystalline lysine) was added to the simple nursery regimen. Pigs fed the complex nursery regimen generally had greater feed intake and rate of gain, resulting in a 3 lb/pig advantage at the end of the nursery phase. As in Experiment 1, there were no nursery regimen × grow-finish regimen interactions that would indicate compensatory gain, with 1.8 additional days required to reach the 250 lb market weight for pigs fed the simple nursery regimen. In conclusion, the combined results of both experiments indicated that for each 1 lb advantage at the end of the nursery phase, days to a market wt of 250 lb were reduced by .6 to .7 d.

(Key Words: Compensatory Gain, Diet Complexity, Grow-finish, Lysine, Nursery.)

Introduction

During the last decade, much research has been focused on phase-feeding programs for swine. The concept of phase feeding dictates use of multiple diets to better match the continuously changing nutrient needs of growing pigs. If done properly, such systems ensure adequate intake of essential nutrients, yet minimize nutrient excesses that are of no benefit to the pigs, add cost to diets, and end as excess nutrients excreted into the environment.

Current recommendations for phase-feeding programs commonly range from two to four diets used in the nursery and from two to five diets used in the growing-finishing period. Obviously, use of many diets requires more storage facilities for ingredients and diets and careful management to ensure that pigs are given the appropriate diet for each phase of growth. Furthermore, multi-phase feeding programs typically are formulated to maximize growth performance with use of high quality (and expensive) ingredients, such as edible grade milk products and highly refined blood products. Thus, many producers question the return on investment of time and money unless these improvements result in fewer days to market, greater rate and efficiency of gain, and improved carcass merit.

The experiments reported herein were designed to determine the effects of a highly fortified, multiple-phase feeding program on growth performance from weaning through finishing and on carcass leanness in market hogs. Special attention was given to the effects of nutritional regimen during the nursery phase (i.e., high nutrient density diets vs simple diets) on subsequent growth performance during the grow-finish phase.

Procedures

In Experiment 1, 224 weanling pigs were used. There were seven pigs/pen and 16 pens/treatment in the 37-d nursery assay. Diet treatments were: 1) simple ingredients/low-lysine diet formulation (corn-soybean meal-dried whey-based diet with 1.25% lysine for d 0 to 23 and a corn-soybean meal-based diet with 1.1% lysine for d 23 to 37) and 2) complex ingredients/ high-lysine diet formulation (spray-dried blood products, lactose, and other specialty ingredients with 1.5% lysine for d 0 to 9 and 1.25% lysine for d 9 to 23, and a corn-soybean meal-based diet with 1.1% lysine for d 23 to 37). All nursery diets were fed in pelleted form. These diet regimens were fed to pigs that had been divided into four weight groups (light, heavy-light, light-heavy, and heavy), such that the overall treatment design was a 2 × 4 factorial with main effects of diet regimen and initial weight group.

The pigs were housed in 4 ft × 5 ft pens with woven-wire flooring. Room temperatures were 90, 87, 84, 80, and 75°F for weeks 1 to 5, respectively. Each pen had a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. The pigs were weighted on d 9, 23, and 37 of the experiment to allow calculation of average daily gain (ADG), average daily feed intake (ADFI), and feed/gain (F/G).

At the end of the nursery assay, the 16 pens from the middle two weight groups (i.e., heavy-light and light-heavy) were moved to a modified open-front finishing building (112 pigs total) and assigned to finishing treatments. The pigs were housed seven/pen with four pens per treatment. Each pen was 6 ft × 16 ft, with a two-hole self-feeder and nipple waterer to allow ad libitum consumption of feed and water. The finishing treatments were: 1) 2-step regimen (.8 and .6% lysine to 150 and 250 lb, respectively) and 2) 4-step regimen (.95, .8, .7, and .6% lysine to 100, 150, 200, and 250 lb, respectively). The diets for the growing-finishing period were fed in meal form. The combination of nursery treatment and finishing treatment yielded a 2 × 2 factorial arrangement, with main effects of simple vs complex nursery regimen and 2- vs 4-step finishing regimen.

As the average weight of pigs in each pen reached 250 lb, the pigs were scanned for fat depth at the last rib. Fat depth was adjusted to a common live weight by using the formula: fat depth ÷ live wt × overall avg live wt.

For Experiment 2, 160 pigs were used. There were five pigs/pen and 16 pens/treatment in the 35-d nursery assay. Diet treatments were: 1) simple diet formulation (corn-soybean meal-wheat gluten-dried whey-based diet with 1.5% lysine for d 0 to 7, corn-soybean meal-dried whey-based diet with 1.25% lysine for d 7 to 21, and a corn-soybean meal-based diet with 1.1% lysine for d 21 to 35) and 2) the same complex diet formulation used in Experiment 1. These two diet regimens were fed to pigs that had been divided into four weight groups, such that the treatment design was a 2 × 4 factorial as in Experiment 1. Housing and management were the same as in Experiment 1, except that the pigs and feeders were weighed on d 7, 21, and 35 of the experiment.

At the end of the nursery assay, the two pens of each treatment with the greatest initial body weights were pooled, and this process was repeated with the next two pens for each treatment, and so on, so that 16 pens of 10 pigs were generated from the original 32 nursery pens. These 16 pens were moved to the finishing building and fed the same diet regimens used in Experiment 1, with the same housing and management procedures. Thus, the treatment design for the finishing phase was a 2 × 2 factorial, with main effects of simple vs complex nursery regimen and 2- vs 4-step finishing regimen. As in Experiment 1, the study was terminated for each pen when the pigs averaged 250 lb.

Results and Discussion

For Experiment 1, ADG, ADFI, and F/G were improved ($P<.01$) by feeding the complex diet vs the simple/low-lysine diet. Also, ADFI was less and efficiency of gain was greater for the smaller vs the larger pigs (i.e., linear effect of initial weight, $P<.01$). These responses were not completely independent, however, because ADG and ADFI showed a marked improvement as initial weight was increased for pigs fed the simple/low-lysine regimen vs much smaller increases in ADG and ADFI as initial weight was increased for pigs fed the complex regimen (diet complexity × quadratic effect of initial wt interactions, $P<.10$ and $P<.05$, respectively).

For d 9 to 23, d 23 to 37, and overall, pigs fed the complex regimen continued to eat more feed ($P<.01$) and have greater ADG ($P<.05$) than pigs fed the simple/ low-lysine regimen. Note, however, that the heaviest groups of pigs given the simple/low-lysine regimen had ADFI and ADG similar to those of the contemporary weight block fed the complex regimen. This indicates that, for the pigs with a weaning weight of 15 lb, the diet with a great variety of expensive ingredients was probably not necessary. However, this does not negate the marked improvement in growth performance of the smaller pigs when fed the complex regimen compared to the simple/low-lysine. Thus on average, pigs fed the complex diet regimen had a 5 lb/pig advantage in body wt at the end of the nursery phase compared to those fed the simple/low-lysine regimen.

For growing-finishing, there were few effects of nursery or growing-finishing diet regimen. Pigs given the complex regimen in the nursery phase had greater initial weights ($P<.01$), but this did not result in greater growth performance in the finishing phase. However, the 5 lb/pig advantage at the end of the nursery phase for these pigs was maintained, resulting in 3.6 fewer days required to reach the 250 lb slaughter weight.

Pigs fed the 4-step finishing regimen had 3% greater ($P<.10$) ADG than pigs fed the 2-step regimen. We should note, however, that this response was consistent for pigs given the complex and simple/low-lysine regimens (i.e., no nursery regimen × finishing regimen interaction). Thus, there was no compensatory growth for lost performance in the nursery phase.

For Experiment 2, the diets were again formulated with and without the complex mixture of dried blood products, fishmeal, yeast product, and flavor. However, for the simple diet regimen, wheat gluten, crystalline lysine, and additional soybean meal were used to bring the initial diet to the same lysine concentration (1.5%) as used in the complex ingredient regimen.

As in Experiment 1, pigs responded to the complex regimen with greater ADFI and ADG throughout most of the nursery phase. It is important to note that even from d 21 to 35, when the pigs were consuming the same phase III diet, ADFI and ADG were greater ($P<.05$) for pigs initially fed the more complex diet. Thus, the early response (d 0 to 7 and d 7 to 21) to improved nutritional status was still having an effect in the last 14 d of the nursery period. The response to the complex regimen yielded a 3 lb/pig advantage at the end of the nursery phase, which was less than observed in Experiment 1. However, remember that in Experiment 1, the simple regimen initially had a low concentration of lysine (i.e., 1.25%).

For the growing-finishing phase of Experiment 2, ADG was actually decreased slightly (P<.10) by feeding the 4-step regimen vs the 2-step regimen. This occurred primarily from the unexpectedly poor performance of pigs given the complex nursery regimen and the 4-step growing-finishing regimen. This response is probably an artifact in the data. In contrast with ADG, efficiency of gain was increased by 8% for pigs fed the 4-step regimen. Nursery regimen did not affect growth performance in the finishing phase, but the 3 lb advantage at the end of the nursery phase resulted in 1.8 fewer d needed to reach market weight.

In conclusion, nursery pigs responded to improved nutritional status resulting from both nutrient concentrations and ingredients used in the diet. That improved performance in the nursery phase resulted in fewer days to market, such that for every 1 lb advantage at the end of the nursery phase, approximately .6 to .7 d less was needed to reach a market weight of 250 lb. This value is considerably less than the 1 lb of nursery body wt = 3 d less to market reported by some researchers. Nonetheless, our data do indicate that compensatory gain during growing-finishing did not negate the advantages achieved during the nursery-phase. The question then becomes whether the economic benefits of 2 to 3 fewer days to market compensate for the additional costs of a complex nursery diet regimen.

Table 1. Diet Composition for the Nursery Phases of Experiments 1 and 2[a]

	Simple			Complex		
Item	Phase I	Phase II	Phase III	Phase I	Phase II	Phase III
Corn	27.05	42.31	64.30	34.79	45.62	64.30
Soybean meal	25.05	30.30	28.90	15.02	24.61	28.90
Fishmeal	–	–	–	2.00	–	–
Plasma protein	–	–	–	7.50	–	–
Blood meal	–	–	–	2.50	2.50	–
Wheat gluten	10.00	–	–	–	–	–
Whey	20.00	20.00	–	20.00	20.00	–
Lactose	10.00	–	–	10.00	–	–
Choice white grease	3.00	3.00	3.00	3.00	3.00	3.00
Dicalcium phosphate	2.20	1.88	1.98	2.07	1.98	1.98
Limestone	.45	.61	.60	.27	.56	.60
Salt	.20	.20	.30	–	.10	.30
KSU vitamin premix	.25	.25	.25	.25	.25	.25
KSU mineral premix	.15	.15	.15	.15	.15	.15
KSU selenium premix	.05	.05	.05	.05	.05	.05
Lysine-HCl	.50	.10	.12	–	–	.12
Methionine	–	–	–	.05	.03	–
Copper sulfate	.10	.10	.10	.10	.10	.10
Antibiotics[b]	1.00	1.00	.25	1.00	1.00	.25
Pellet binder	–	.05	–	.05	.05	–
Yeast culture	–	–	–	1.00	–	–
Probiotic flavor	–	–	–	.20	–	–
Total	100.00	100.00	100.00	100.00	100.00	100.00
<u>Calculated analyses</u>						
CP, %	23.4	19.6	18.5	21.05	19.6	18.5
Lysine, %	1.50	1.25	1.10	1.50	1.25	1.10
Ca, %	.9	.9	.8	.9	.9	.8
P, %	.8	.8	.7	.8	.8	.7

[a] For Experiment 1, pigs were given the phase II diet for d 0 to 23 and the phase III diet for d 23 to 35 to give the simple/low-lysine treatment. For Experiment 2, all three diets were used for both the simple and complex regimens.

[b] Apralan in phases I and II diets and Mecadox in phase III.

Table 2. Diet Composition for the Growing-Finishing Phases of Experiments 1 and 2

	Lysine, %[a]			
Item	.95	.80	.70	.60
Sorghum	71.40	76.45	80.70	83.70
Soybean meal	25.40	20.25	16.50	13.50
Monocalcium phosphate	1.35	1.45	1.05	1.05
Limestone	.95	.95	.95	.95
Salt	.30	.30	.30	.30
KSU vitamins premix	.25	.25	.25	.25
KSU minerals premix	.10	.10	.10	.10
KSU selenium premix	.05	.05	.05	.05
Antibiotic[b]	.20	.20	.10	.10
Total	100.00	100.00	100.00	100.00
Calculated analyses				
CP, %	18.80	16.40	14.80	13.60
Lysine, %	.95	.80	.70	.60
Ca, %	.75	.75	.65	.65
P, %	.65	.65	.55	.55

[a] For the 2-step regimen, pigs were fed the diets with .80 and .60% lysine for the growing (to 150 lb body wt) and finishing (150 to 250 lb body wt) phases, respectively. For the 4-step regimen, pigs were fed the diets with .95, .80, .70, and .60% lysine to 100, 150, 200, and 250 lb body wt, respectively.

[b] Supplied 200 and 100 g/ton chlortetracycline in the growing and finishing phases, respectively.

Table 3. Effects of Diet Complexity, Lysine Concentration, and Initial Body Weight on Growth of Nursery Pigs (Exp. 1)[a]

	Simple[b]				Complex[b]				
Item	Lgt	Lgt-Hvy	Hvy-lgt	Hvy	Lgt	Lgt-hvy	Hvy-lgt	Hvy	CV
Initial wt, lb[h]	10.3	12.2	13.4	15.8	10.4	12.2	13.3	15.8	4.2
Final wt, lb[e,h]	41.5	43.1	44.3	50.7	47.0	49.8	50.5	52.5	5.7
d 0 to 9									
ADG, lb[e,j]	.42	.42	.45	.48	.63	.69	.69	.59	13.3
ADFI, lb[e,h,i,k]	.44	.49	.50	.62	.59	.66	.68	.62	9.9
F/G[e,h]	1.05	1.17	1.11	1.29	.94	.96	.99	1.05	8.2
d 9 to 23									
ADG, lb[e]	.88	.78	.82	.85	.94	.95	1.00	.92	10.3
ADFI, lb[e,g]	1.16	1.15	1.21	1.35	1.26	1.33	1.35	1.35	8.4
F/G[c,h]	1.32	1.47	1.48	1.59	1.34	1.40	1.35	1.47	6.6
d 23 to 37									
ADG, lb[d,f]	1.07	1.15	1.07	1.34	1.28	1.29	1.22	1.33	10.6
ADFI, lb[e,h]	1.82	1.85	1.84	2.11	2.04	2.18	2.11	2.35	7.3
F/G[i]	1.70	1.61	1.72	1.57	1.59	1.69	1.73	1.77	6.9
Overall (d 0 to 37)									
ADG, lb[e]	.84	.83	.83	.94	.99	1.01	1.01	.99	7.9
ADFI, lb[e,h]	1.23	1.26	1.27	1.46	1.40	1.49	1.48	1.54	6.8
F/G[d,h]	1.46	1.52	1.53	1.55	1.41	1.48	1.46	1.56	4.6

[a] A total of 224 pigs (7 pigs/pen and 16 pens/treatment).

[b] Lysine regimens were 1.25, and 1.1% and 1.5, 1.25, and 1.1% and 1.25 for the simple and complex formulations, respectively, for d 0 to 9, 9 to 23, and 23 to 37.

[c,d,e] Effect of diet complexity (P<.10, P<.05, P<.01, respectively).

[f,g,h] Linear effect of initial wt (P<.10, P<.05, P<.01, respectively).

[i] Diet complexity × linear effect of initial wt (P<.05).

[j,k] Diet complexity × quadratic effect of initial wt (P<.10, P<.05, respectively).

Table 4. Effects of Diet Complexity and Lysine Concentrations in the Nursery Phase on Subsequent Growing-Finishing Performance of Pigs (Experiment 1)[a]

	Simple-Nursery		Complex-Nursery		
Item	.8/.6 Lysine (gro-fin)	.95/.8/.7/.6 Lysine (gro-fin)	.8/.6 Lysine (gro-fin)	.95/.8./.7/.6 Lysine (gro-fin)	CV
Initial wt, lb[c]	44.9	43.5	50.5	49.7	5.1
Final wt, lb	252.4	256.3	253.8	257.5	2.0
Days to 250 lb[b]	118.2	116.0	115.1	112.0	2.9
ADG, lb[d]	1.74	1.77	1.73	1.79	2.8
ADFI, lb	5.19	5.43	5.45	5.41	4.9
F/G	2.98	3.08	3.16	3.02	4.8
Last rib fat depth, in	.87	.87	.83	.90	9.0

[a] A total of 112 pigs was used (7 pigs/pen and 4 pens/treatment).
[bc] Effect of nursery diet regimen (P<.10, P<.01, respectively).
[d] Effect of finishing diet regimen (P<.10).

Table 5. Effects of Diet Complexity at Similar Lysine Concentrations and Initial Body Weight on Growth of Nursery Pigs (Experiment 2)[a]

	Simple-Nursery[b]				Complex-Nursery[b]				
Item	Lgt	Lgt-hvy	Hvy-lgt	Hvy	Lgt	Lgt-hvy	Hvy-lgt	Hvy	CV
Initial wt, lb[h,k]	9.8	11.2	12.5	14.9	9.8	11.1	12.4	14.8	3.0
Final wt, lb[d,h,j]	32.7	32.0	35.3	41.2	37.1	35.0	38.4	43.4	10.6
d 0 to 7									
ADG, lb[e,g]	.25	.28	.26	.35	.37	.37	.40	.53	29.3
ADFI, lb[e,h]	.29	.29	.34	.37	.41	.43	.40	.54	19.0
F/G	1.16	1.04	1.31	1.06	1.11	1.16	1.00	1.02	22.1
d 7 to 21									
ADG, lb[g]	.56	.56	.61	.67	.62	.62	.63	.75	15.8
ADFI, lb[h]	1.06	1.12	1.21	1.25	1.11	1.10	1.15	1.21	9.5
F/G[e,i]	1.86	2.00	1.98	1.87	1.79	1.77	1.83	1.61	11.0
d 21 to 35									
ADG, lb[d,k]	.96	.78	.87	1.05	1.12	.89	1.02	1.13	16.3
ADFI, lb[d,h,k]	1.89	1.63	1.99	2.22	2.12	1.87	1.96	2.40	10.5
F/G[f]	1.97	2.09	2.29	2.11	1.89	2.10	1.92	2.12	10.5
Overall (d 0 to 35)									
ADG, lb[e,j]	.65	.59	.64	.71	.79	.67	.74	.85	13.5
ADFI, lb[c,h,k]	1.24	1.16	1.34	1.46	1.37	1.26	1.33	1.55	9.0
F/G[c]	1.91	1.97	2.09	2.06	1.73	1.88	1.80	1.82	10.2

[a] A total of 160 pigs (5 pigs/pen and 16 pens/treatment).
[b] Lysine regimens were 1.5, 1.25, and 1.1% for d 0 to 7, 7 to 21, and 21 to 35, respectively, for simple and complex formulations.
[c,d,e] Effect of diet complexity (P<.10, P<.05, P<.01, respectively).
[f,g,h] Linear effect of initial wt (P<.10, P<.05, <.01, respectively).
[i,j,k] Quadratic effect of initial wt (P<.10, P<.05, P<.01, respectively).

Table 6. Effects of Diet Complexity in the Nursery Phase on Subsequent Growing-Finishing Performance of Pigs (Experiment 2)[a]

	Simple-Nursery		Complex-Nursery		
Item	.8/.6 Lysine (gro-fin)	.95/.8/.7/.6 Lysine (gro-fin)	.8/.6 Lysine (gro-fin)	.95/.8./.7/.6 Lysine (gro-fin)	CV
Initial wt, lb	35.6	36.0	38.9	39.6	12.8
Final wt, lb[d]	247.6	253.0	251.2	249.8	1.4
Days to 250 lb	121.1	119.8	115.7	121.6	4.4
ADG, lb[b,d]	1.78	1.79	1.83	1.72	3.2
ADFI, lb	5.73	6.05	5.75	5.90	5.3
F/G[c]	3.22	3.38	3.14	3.51	5.3

[a] A total of 160 pigs was used (10 pigs/pen and 4 pens per treatment).
[b,c] Effect of finishing diet regimen (P<.10, P<.05, respectively).
[d] Interaction of nursery and finishing regimens (P<.10).

INFLUENCE OF DIETARY LYSINE ON GROWTH PERFORMANCE AND TISSUE ACCRETION RATES OF HIGH-LEAN GROWTH GILTS FED FROM 80 TO 160 LB[1]

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Summary

One-hundred eight high-lean growth gilts (75.5 lb initial weight) were used to determine the dietary lysine requirement to maximize growth performance and protein accretion from 80 to 160 lb. The experiment was designed as a randomized complete block, with initial weight serving as the blocking factor. Six dietary treatments were included, ranging from .54 to 1.04% digestible lysine (.69 to 1.25% total dietary lysine). Pigs were housed in pens of three, with six replicate pens/treatment. Pig weights and feed disappearance were collected weekly to calculate average daily gain (ADG), average daily feed intake ADFI, and feed efficiency (F/G). Initially, six pigs were slaughtered to determine baseline carcass composition. When the mean weight for pigs in a pen reached 120 and 160 lb, one pig per pen was randomly selected and slaughtered for carcass analyses. The right side of each carcass was ground twice and sampled to determine carcass composition and lean tissue (crude protein) accretion rate. Average daily gains were greater for gilts fed increased dietary lysine from 80 to 120 lb, from 120 to 160 lb, and from 80 to 160 lb. Average daily feed intakes from 80 to 120 and from 120 to 160 lb were not influenced by dietary lysine. However, ADFI for the entire experiment tended to decrease as digestible lysine increased. Increased dietary lysine resulted in improved F/G from 80 to 120 lb and from 120 to 160 and 80 to 160 lb. Gilts fed increased digestible lysine had greater CP accretion from 80 to 120 lb, 120 to 160 lb, and 80 to 160 lb . Based on the feed intake observed in this study, the high-lean growth gilt requires at least 18 to 19 and 22 g/d lysine intakes from 80 to 120 lb and from 120 to 160 lb, respectively, to maximize ADG, F/G, and lean accretion.

(Key Words: Pigs, Growth, Carcass Composition, Genotype, Gilts.)

Introduction

The National Research Council (1988) reported extensive research on dietary lysine estimates for growing-finishing swine. However, the extent of experiments pertaining to dietary lysine requirements based on protein accretion rate or carcass leanness potential is limited. Previous research conducted at Kansas State University indicated that high-lean growth gilts exhibit a greater response to dietary lysine than barrows. Therefore, gilts had a greater lean deposition rate and improved lean efficiency, even though barrows had a greater average daily gain. Similar research conducted by the NCR-42 committee on swine nutrition indicated that gilts had a greater response to increased crude protein and lysine compared to barrows in terms of rate and efficiency of lean deposition. Thus, nutritional programs based upon genetics and gender are a necessity to

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[2] Nutri-Quest, Inc., St. Louis, MO 63017.

maximize both rate and efficiency of lean deposition. Therefore, the objective of this experiment was to determine the dietary lysine requirement to optimize growth performance and protein accretion rate for high-lean growth gilts fed from 80 to 160 lb.

Procedures

Animals. One hundred eight high-lean growth gilts (initially 75.5 lb) were used to determine the dietary lysine requirement to optimize growth performance and lean tissue deposition with six dietary treatments. The gilts were delivered to the Kansas State University Swine Research Center and were fed a corn-soybean meal diet containing .90% lysine during a 7 day acclimation period. Three pigs were housed per pen (4 ft × 15 ft pens with solid flooring) in an open-fronted building with six replicate pens per treatment. The trial was conducted from August 17 to November 9, 1992, and when temperatures exceeded 80°F, drip coolers were activated to wet the pigs for 3 out of every 15 min. Each pen contained a single-hole feeder and a nipple waterer to accommodate *ad libitum* access to feed and water. Pig weights and feed disappearance were collected weekly to determine ADG, ADFI, F/G, and lysine intake. When the mean weight of pigs in a pen reached 120 and 160 lb, one pig per pen was randomly removed and slaughtered.

Diet Formulation. Dietary treatments ranged from .54 to 1.04% digestible lysine, with total calculated dietary lysine ranging from .68 to 1.25% (Table 1). Corn-soybean meal diets were balanced to digestible lysine levels. Other amino acid levels were set using an ideal amino acid ratio to assure that lysine was the first limiting amino acid. Calculated amino acid digestibility coefficients were used for the feed ingredients. The corn-soybean meal ratio was altered to increase the dietary lysine content. L-lysine-HCl was maintained at .05% of the complete diet, so that lysine bioavailability was not influenced by high inclusion of synthetic lysine. All diets contained 3% soybean oil. The lysine:Mcal ratio of the diet ranged from 2.14 to 3.65. All other nutrients either met or exceeded NRC (1988) estimates for the 20 to 50 kg pig.

Carcass Composition. Six gilts were randomly selected for slaughter at 80 lb and the right side of the carcass was ground to determine initial empty body composition (percentage of moisture, crude protein, lipid, and ash). When the pen mean weight of pigs in a pen equalled 120 and 160 lb, one pig from each pen (six pigs/treatment) was slaughtered for carcass analysis. The head, leaf fat, and viscera were removed at slaughter and were not included in tissue accretion rate determination. At 24 h postmortem, the right side of each carcass was ground once through a .47 in plate and once through a .35 in plate and homogenized for 3 min in a ribbon-paddle mixer. From the chemical analysis, the lb of CP, lipid, ash, and DM were determined for each carcass based upon cold carcass weight. Moisture content was determined by subtracting the percentage DM from 100%. Chemical components (DM, CP, lipid, and ash) from the initial six gilts were averaged and expressed as a percentage of live weight prior to slaughter. Thus, initial composition, determined from percentage chemical composition of live weight, was subtracted from chemical composition determined at either 120 or 160 lb. Tissue accretion rates were calculated as the difference between final (120 or 160 lb) and initial (80 lb) composition, divided by the days on test. Intermediate accretion rates (120 to 160 lb) were determined by subtracting the chemical composition as a percentage of live weight at 120 lb from the final composition and dividing by the days on test. The mean of six gilts for each treatment was used as the initial composition for their respective treatment group at 120 lb.

Results

Growth Performance. Increasing digestible lysine improved ADG from 80 to 120 lb (linear, P<.01), from 120 to 160 lb (linear, P<.10), and from 80 to 160 lb (linear, P<.01; Table 2). Conversely, ADFI was not influenced (P>.35) by dietary treatment from 80 to 120 and from 120 to 160 lb. However, ADFI tended to decrease (quadratic, P<.10) as digestible lysine increased from 80 to 160 lb. Thus, greater ADG with similar ADFI improved F/G from 80 to 120 lb (linear, P<.01), and from 120 to 160 and 80 to 160 lb (quadratic, P<.01). Breakpoint analysis using a quadratic model from 120 to 160 lb indicated that G/F was maximum for gilts fed .83% digestible lysine. However, for the entire experiment (80 to 160 lb), breakpoint analysis indicated maximum F/G (quadratic model) for gilts fed .87% digestible lysine, respectively. Lysine intake (g/d) increased (linear, P<.01) from 80 to 120, from 120 to 160, and from 80 to 160 lb as a result of increased diet lysine fortification, rather than an increase in ADFI.

Tissue Accretion Rates. From 80 to 120 lb, moisture and CP accretion increased (linear, P<.01) for gilts fed increasing digestible lysine (Table 3). Moisture and CP accretion improved by 117 and 26 g/d, respectively, in gilts fed 1.04% compared with .54% digestible lysine. Conversely, lipid accretion decreased (linear, P<.01) by 47 g/d as digestible lysine was increased. Ash accretion was not influenced (P=.30) by dietary treatment. Lean gain and lean efficiency were both improved (linear, P<.01) for gilts fed increased digestible lysine. From 120 to 160 lb, greater dietary lysine tended to increase moisture accretion (quadratic, P<.10) and increased CP accretion (linear, P<.05; quadratic, P<.10). Moisture and CP accretion were maximized for gilts fed .94% digestible lysine; 150 and 53 g/d, respectively, greater than gilts fed .54% digestible lysine. However, CP accretion was maximum using a quadratic model for gilts fed .74% digestible lysine. Lipid (P=.60) and ash (P=.20) accretion were not influenced by dietary lysine from 120 to 160 lb. Numerically, lipid accretion appears to respond in a quadratic fashion, with minimal lipid accretion for gilts fed .84% digestible lysine. However, the coefficient of variation was large. Ash accretion was not influenced (P=.20) by dietary treatment. For the entire experiment (80 to 160 lb), moisture and CP accretion increased (linear, P<.01; quadratic, P<.05) for gilts fed greater digestible lysine. Moisture and CP accretion were again maximum for gilts fed .94% digestible lysine; 142 and 40 g/d greater than gilts fed .54% digestible lysine. Conversely, lipid accretion decreased (linear, P<.05; quadratic, P<.10) as digestible lysine increased. The lowest lipid accretion was observed for gilts fed a .84% digestible lysine diet, 34 g/d lower than that for gilts fed .54% digestible lysine. Dietary treatment did not influence (P=.15) ash accretion for the entire experiment. Crude protein accretion was maximized at .79%, whereas lipid accretion was minimized at .71% digestible lysine using a linear-linear model from 34 to 72.5 kg. Both lean gain (linear, P<.05) and lean efficiency (quadratic, P<.05) increased for gilts fed increased digestible lysine.

Discussion

The results of this experiment indicate that the dietary lysine requirement to optimize growth performance and protein accretion for the high-lean growth gilt is greater than current National Research Council estimations. Although ADG, F/G, and protein accretion rate improved linearly from 80 to 120 lb, they appeared to plateau for gilts fed .94% (1.15% total lysine or 19 g/d). These data represent a 4 to 5 g/d (26%) increase above current NRC estimates. Also, these data show the relationship between genetics and protein deposition (lean gain/d). When dietary lysine was under fed, protein accretion rates and lipid accretion rates were nearly identical. However, protein deposition increased while lipid deposition decreased for gilts fed greater dietary lysine. From 120 to 160 lb, gilts fed a .84% digestible lysine diet

(1.05% total lysine or 22 g/d) had the maximal ADG and the best F/G ratio. However, protein deposition was further improved by increasing the digestible lysine to .94%. These data represent a 15% greater lysine intake than current NRC estimates. On the other hand, ADFI was not influenced by dietary lysine from 80 to 120 and from 120 to 160 lb. However, the gilts in this experiment consumed 11% less than NRC estimates. Therefore, the increase in dietary lysine over NRC estimates is both a function of lower feed intake and a greater lysine need for protein deposition. Thus, genetic potential will dictate the lysine requirement to optimize growth performance and protein accretion rate.

When feed costs per lb of live weight gain are assessed, the cost from 80 to 120 lb is approximately $.12 to .14 per lb of live weight gain regardless of dietary lysine content. However, when the feed cost per lb of lean gain is analyzed, increasing dietary lysine results in decreased cost per lb of lean tissue deposited. Lean tissue deposition (protein accretion) was maximized for gilts fed .94% digestible lysine (1.15% total lysine), whereas cost of lean deposition was minimized at $.27/lb at the same dietary lysine. A similar pattern was noted for gilts fed from 120 to 160 lb. Feed cost per lb of live weight gain was similar for gilts fed .54 to .84% digestible lysine. However, feed cost increased by $.04 to .05/lb when digestible lysine was increased above .84%. The feed cost per lb of lean gain was minimized at $.27/lb for gilts fed a .84% digestible lysine (1.05% total lysine) diet. Again, this was the same level of dietary lysine that maximized lean tissue deposition (protein accretion).

In summary, the data from this experiment indicate the importance of developing nutrition programs based on feed intake and genetic potential for lean deposition. The results suggest that the high-lean growth gilt requires at least 18 to 19 g/d (1.15% total lysine) and 22 g/d (1.05% total lysine) of lysine intake from 80 to 120 and from 120 to 160 lb, respectively, for maximum ADG and lean tissue accretion. In conjunction, feed efficiency and cost/lb of lean tissue deposition are optimized when lean tissue deposition (protein accretion) is maximized.

Table 1. Diet Composition

	Digestible Lysine, %					
Item, %	.54	.64	.74	.84	.94	1.04
Corn	79.62	75.69	71.71	67.74	63.73	59.75
Soybean meal (48.5% CP)	14.08	18.09	22.11	26.12	30.14	34.15
Soybean oil	3.00	3.00	3.00	3.00	3.00	3.00
L-lysine HCl	.05	.05	.05	.05	.05	.05
L-threonine	—	.01	.03	.03	.07	.10
DL-methionine	—	.001	.03	.07	.11	.14
L-tryptophan	.001	—	—	—	—	—
Monocalcium phosphate (21% P)	1.60	1.53	1.46	1.38	1.31	1.24
Limestone	.95	.93	.92	.90	.89	.87
Salt	.35	.35	.35	.35	.35	.35
Trace mineral premix	.15	.15	.15	.15	.15	.15
Vitamin premix	.20	.20	.20	.20	.20	.20
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis, %						
Crude Protein (N x 6.25)	14.86	15.78	17.95	19.08	20.99	20.86
Total Dietary Lysine	.68	.79	.91	1.02	1.14	1.25
Ca	.75	.75	.75	.75	.75	.75
P	.65	.65	.65	.65	.65	.65
Mcal/lb	1550	1550	1550	1550	1550	1550

Table 2. The Effect of Increased Digestible Lysine on Growth Performance of High-Lean Growth Gilts Fed from 80 to 120 and 160 lb[a]

	Digestible Lysine, %						
Item	.54	.64	.74	.84	.94	1.04	CV
ADG, lb							
80 to 120 lb[b]	1.42	1.56	1.56	1.72	1.85	1.80	8.77
120 to 160 lb[c]	1.68	1.77	1.82	1.91	1.89	1.84	10.44
80 to 160 lb[b]	1.51	1.65	1.63	1.82	1.92	1.82	9.26
ADFI, lb							
80 to 120 lb	3.86	3.79	3.73	3.72	3.78	3.61	10.56
120 to 160 lb	5.22	5.14	4.80	4.63	5.08	4.82	10.82
80 to 160 lb[d]	5.20	5.18	4.71	5.00	5.18	5.20	7.81
F/G							
80 to 120 lb[b]	2.73	2.44	2.38	2.17	2.05	2.02	8.68
120 to 160 lb[be]	3.13	2.94	2.68	2.43	2.68	2.64	9.77
80 to 160 lb[be]	3.45	3.15	2.90	2.75	2.70	2.87	5.14
Lysine intake, g/d							
80 to 120 lb[b]	13.31	13.75	16.57	17.87	20.21	21.48	10.36
120 to 160 lb[b]	17.99	18.66	21.34	22.25	27.17	28.66	11.26
80 to 160 lb[b]	14.86	15.35	16.86	19.39	22.18	24.02	7.86

[a] A total of 108 pigs, three pigs/pen from 80 to 120 lb and two pigs/pen from 120 to 160 lb; six replicate pens/treatment.

[b] Linear effect of digestible lysine (P<.01).

[c] Linear effect of digestible lysine (P<.10).

[d] Quadratic effect of digestible lysine (P<.10).

[e] Quadratic effect of digestible lysine (P<.01).

Table 3. The Effect of Increased Digestible Lysine on Moisture, Protein, Lipid, and Ash Accretion in High-Lean Growth Gilts Fed from 80 to 120 and 160 lb[a]

	Digestible Lysine, %						
Item, g/d	.54	.64	.74	.84	.94	1.04	CV
80 to 120 lb							
Moisture[b]	258	282	292	344	366	375	10.72
CP[b]	77	84	89	103	104	103	15.69
Lipid[b]	96	74	60	72	70	49	37
Ash	14	11	15	16	13	17	32.64
Lean gain/d, lb[b]	.67	.62	.69	.81	.91	.90	13.27
Lean/ADFI[b]	5.76	6.09	5.42	4.69	4.17	4.09	11.30
120 to 160 lb							
Moisture[c]	305	319	352	379	455	314	23.11
CP[cd]	85	91	131	114	138	111	27.37
Lipid	123	127	103	73	94	127	53.58
Ash	17	31	24	21	16	25	35.64
80 to 160 lb							
Moisture[be]	286	313	329	372	428	365	9.15
CP[be]	83	90	111	113	123	110	13.78
Lipid[cd]	107	99	79	73	80	84	27.83
Ash	16	20	19	21	15	21	21.04
Lean gain/d, lb[d]	.73	.84	.94	1.02	1.01	.95	23.25
Lean/ADFI[de]	7.16	6.61	5.26	4.89	5.44	5.47	27.96

[a] Calculated from 36 pigs each at a pen mean weight of 120 and 160 lb, one pig/pen, six pens/treatment.
[b] Linear effect of digestible lysine ($P<.01$).
[c] Quadratic effect of digestible lysine ($P<.10$).
[d] Linear effect of digestible lysine ($P<.05$).
[e] Quadratic effect of digestible lysine ($P<.05$).

INFLUENCE OF DIETARY LYSINE ON CARCASS CHARACTERISTICS OF HIGH-LEAN GROWTH GILTS FED FROM 80 TO 160 LB[1]

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Summary

Seventy-two high-lean growth gilts (initially 75.5 lb BW) were used to determine the influence of dietary lysine on carcass characteristics at 120 and 160 lb. Gilts were randomly selected for slaughter when the average weight of pigs in the pen equaled or exceeded 120 and 160 lb. The experiment was designed as a randomized complete block, with initial weight serving as the blocking factor. Six dietary treatments were included, ranging from .54 to 1.04% digestible lysine (.69 to 1.25% total dietary lysine). At 120 lb, hot carcass weight decreased and then increased as did dressing percentage for gilts fed increased dietary lysine. Average backfat thickness and 10th rib fat depth were not influenced by dietary treatment. However, longissimus muscle area (loineye) was increased for gilts fed greater dietary lysine. Kidney fat and total carcass lipid decreased but carcass moisture increased as dietary lysine increased. The decreased carcass lipid content resulted in reduced longissimus muscle marbling at 120 lb. For gilts fed to 160 lb, hot and chilled carcass weight decreased and then increased as dietary lysine increased. Dressing percentage followed a similar pattern because of the difference in carcass weight. Backfat thickness, 10th rib fat thickness, and kidney fat decreased for gilts fed increased dietary lysine. Carcass moisture and crude protein increased and then decreased as dietary lysine increased. The moisture content was maximal for gilts fed .94% digestible lysine, whereas carcass crude protein was maximal for gilts fed .74% digestible lysine. However, carcass lipid followed an opposite pattern, decreasing and then increasing as dietary lysine increased. Carcass muscle score improved but longissimus muscle marbling decreased for gilts fed greater dietary lysine. The data from this experiment suggest that the high-lean growth gilt requires at least 18 and 22 g/d lysine intakes from 80 to 120 and from 120 to 160 lb, respectively, to optimize longissimus muscle area and minimize carcass lipid content.

(Key Words: Pigs, Genotype, Gilts, Carcass Characteristics.)

Introduction

The emphasis on carcass leanness over the past 5 years has led producers to purchase seed stock from proven genetic sources selected for a high rate of lean deposition. However, improper amino acid and energy nutrition can actually mask the pig's genetic potential. Research from the University of Kentucky has indicated the relationship between lysine intake (crude protein) and genetic potential. The data suggest that pigs selected for a greater rate of lean deposition require increased dietary lysine and energy to sustain increased muscle deposition and increased maintenance requirements. By increasing dietary

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lysine, loin eye area is increased while backfat thickness is decreased, indicating a shift in the composition of weight gain from lipid to muscle tissue. By incorporating lean value marketing programs, the increased muscle deposition can result in greater profit margins for the producer. Thus, the relationship between nutrition and genetic potential must be considered throughout both the growing and finishing phases of growth for both improvements in growth performance and carcass leanness. Therefore, the objective of this experiment was to determine the influence of dietary lysine on carcass characteristics of high-lean growth gilts fed from 80 to 120 and 160 lb.

Procedures

The experimental design and procedures are described in the previous paper. Briefly, 108 (initially 75.5 lb) high-lean growth pigs were housed three pigs/pen with six replicate pens/treatment. Six dietary treatments were fed ranging from .54 to 1.04% digestible lysine (.68 to 1.25% total lysine), increasing by an increment of .1%. The pigs were housed in an open-fronted building with solid concrete flooring. Each pen contained a single hole feeder and a nipple waterer to provide *ad libitum* access to feed and water. When the mean weight of pigs in pen reached 120 and 160 lb, one pig/pen was randomly selected for slaughter to determine carcass characteristics.

Carcass Characteristics. Carcasses were weighed immediately following slaughter and reweighed 24 h postmortem to record hot and chilled carcass weights, respectively. Dressing percentage was determined from the live weight and the hot carcass weight. The kidney fat was removed from each carcass following slaughter and weighed. Backfat thickness was measured at the first and last ribs and last lumbar vertebrae from both the right and left sides of the carcass. All six measurements were averaged to determine the average backfat thickness. Tenth-rib fat depth was measured at 3/4 the length from the midline of the longissimus muscle. Longissimus muscle area at the 10th rib was traced and read with a planimeter. Carcass color, firmness, marbling, and muscle scores were recorded according to NPPC (1991) guidelines. The muscle score index was expanded from a scale of one to three points to a scale of one to six points. The expanded scale set a mid-point at three and allowed for more accurate estimates of carcass muscle.

Results

At 120 lb, live weight and chilled carcass weight were not influenced (P=.69) by dietary lysine (Table 1). However, hot carcass weight tended to decrease and then increase (quadratic, P<.10), resulting in a similar trend in dressing percentage (quadratic, P<.10). Gilts fed increasing dietary lysine levels had a similar average backfat thickness (P=.28) and 10th rib fat depth (P=.21). However, average backfat thickness and 10th rib fat depth numerically decreased for gilts fed increased dietary lysine compared to gilts fed .54% digestible lysine. Dietary lysine positively influenced (linear, P<.05) longissimus muscle area, increasing by .64 in^2 when digestible lysine was increased from .54 to 1.04%. Carcass length was not influenced (P=.39) by dietary treatment. The amount of kidney fat decreased (linear, P<.01) as digestible lysine increased. Carcass moisture was increased (linear, P<.01) and carcass lipid decreased (linear, P<.01) for gilts fed increased dietary lysine. However, carcass crude protein and ash were not influenced (P=.57) by increasing digestible lysine. Visual scores for muscling (P=.15), longissimus color (P=.49), and longissimus firmness (P=.92) were not affected by dietary treatment. However, longissimus marbling tended to decrease (linear, P<.10) for gilts fed increased digestible lysine.

When gilts were slaughtered at 160 lb, live weight was not affected by dietary treatment (Table 2). However, hot and chilled carcass weights were greater (quadratic, P<.05) for gilts fed a .74% digestible lysine diet than a .54 or 1.04% digestible lysine diet. This resulted in increased (quadratic, P<.05) dressing percentage for gilts fed .74% digestible lysine. Average backfat thickness and 10th rib fat depth were decreased (linear, P<.01) for gilts fed increased digestible lysine. Gilts fed 1.04% digestible lysine had .19 and .15 in less average backfat and 10th rib fat depth, respectively, than gilts fed .54% digestible lysine. Longissimus muscle area (P=.20) and carcass length (P=.52) were not influenced by digestible lysine. Kidney fat decreased (linear, P<.01) as digestible lysine increased, resulting in a .57 lb decrease in kidney fat for gilts fed 1.04% compared with .54% digestible lysine. Moisture and crude protein were greater (linear, P<.01; quadratic P<.05) for gilts fed increased digestible lysine. Carcass moisture and crude protein appeared to be maximized for gilts fed between .74 and .94% digestible lysine. Carcass lipid decreased (linear, P<.01) for gilts fed increased digestible lysine. Quality scores for carcass muscling increased (linear, P<.01) and those for marbling decreased (linear, P<.05) as digestible lysine increased from .54 to 1.04% digestible lysine. Longissimus color (P=.94) and firmness (P=.74) scores were not influenced by dietary treatment.

Discussion

As dietary lysine increased from 80 to 120 lb, longissimus muscle area increased but average backfat thickness was not influenced. The carcass composition at 120 lb had decreased lipid content as exemplified by a numerical decrease in backfat thickness and a dramatic decrease in kidney fat. This would suggest a shift in the composition of gain towards a greater lean content. Even though the percentage of protein in the carcass did not increase, the amount of lipid was reduced. This can be explained by the tissue accretion rates described in the previous paper (p. 85), indicating a greater rate of protein and a reduced rate of lipid deposition. Muscle scores also indicate that increased dietary lysine resulted in improved carcass muscling. Although carcasses are not traditionally sold at 85 lb, the carcass quality (color and firmness) did not indicate poorer muscle quality as dietary lysine increased. Also, longissimus muscle marbling was decreased in gilts fed increased dietary lysine

At 160 lb, longissimus muscle area was improved only numerically by increased dietary lysine. However, average and tenth rib backfat thickness were decrease for gilts fed increased dietary lysine. These data again suggest a shift in the composition of gain towards greater muscle deposition. Although crude protein content of the carcasses was not affected by dietary lysine, carcass lipid content decreased and moisture content increased. These shifts in composition would reflect the change in the composition of gain. The decreased lipid content can be explained by decreased backfat thickness and kidney fat weight. Longissimus muscle color and firmness were not influenced by dietary lysine; however, longissimus muscle marbling was decreased. This decrease in marbling would correspond to the decreased carcass lipid.

The results of this experiment suggest that high-lean growth gilts fed from 80 to 120 and 160 lb require at least 18 and 22 g/d, respectively, of lysine intake to maximize carcass leanness and minimize carcass lipid. In our previous paper, we showed that with increasing dietary lysine, total gain was increased (p. 85). In conjunction, the composition of gain was shifted towards greater muscle deposition and decreased lipid deposition. These data further suggested the importance of phase feeding grower pigs diets matched to their genetic potential for optimimal carcass leanness and minimal carcass lipid deposition and, thus, more fully capitalizing on lean value marketing programs.

Table 1. The Effect of Increased Digestible Lysine on Carcass Characteristics, Composition, and Quality in High-Lean Growth Gilts Slaughtered at 120 lb[a]

	Digestible Lysine, %						
Item	.54	.64	.74	.84	.94	1.04	CV
Live wt, lb	120.56	120.56	121.04	118.88	120.05	119.88	2.89
Hot carcass wt, lb[b]	84.49	84.39	80.73	83.69	83.39	83.85	2.04
Chilled carcass wt, lb	82.15	82.09	79.63	82.27	81.88	81.28	2.69
Dressing percentage[b]	69.90	69.85	66.83	69.21	69.01	69.40	2.05
Average backfat thickness, in	.59	.54	.39	.52	.48	.50	19.52
Tenth rib fat depth, in	.45	.59	.33	.42	.34	.49	24.28
Longissimus muscle area, in^2 [c]	3.40	3.70	3.35	3.56	4.00	4.04	9.30
Carcass length, in	25.67	26.08	26.42	25.88	25.38	25.76	2.31
Kidney fat, lb[d]	.61	.48	.42	.63	.30	.36	21.94
Carcass composition, %							
Moisture[d]	61.82	63.80	65.08	64.53	65.51	66.41	5.44
CP (N × 6.25)	17.15	17.67	18.40	17.95	17.89	17.87	6.32
Lipid[d]	14.62	12.63	11.30	11.70	11.30	9.84	13.98
Ash	3.12	2.87	3.23	3.07	2.82	3.07	11.24
Quality							
Muscle score[e]	4.38	3.20	4.44	4.89	4.64	4.58	18.43
Marbling[fg]	2.10	1.57	1.28	1.43	1.59	1.22	31.50
Color[f]	2.44	1.79	2.40	2.00	2.36	2.16	19.84
Firmness[f]	2.86	2.55	2.25	3.05	2.73	2.53	31.73

[a] Calculated from 36 pigs at a pen mean weight of 120 lb, one pig/pen, six pigs/treatment.
[b] Quadratic effect of digestible lysine (P<.10).
[c] Linear effect of digestible lysine (P<.05).
[d] Linear effect of digestible lysine (P<.01).
[e] Carcasses were evaluated on a six point scale ranging from thin muscling (1) to extremely thick muscling (6).
[f] Loins were evaluated on a five point scale according to NPPC (1991) procedures.
[g] Linear effect of digestible lysine (P<.10).

Table 2. The Effect of Increased Digestible Lysine on Carcass Characteristics, Composition, and Quality in High-Lean Growth Gilts Slaughtered at 160 lb[a]

	Digestible Lysine, %						
Item	.54	.64	.74	.84	.94	1.04	CV
Live wt, lb	164.00	159.66	161.16	159.02	161.84	158.67	3.36
Hot carcass wt, lb[b]	111.21	110.69	117.35	114.46	115.14	111.24	2.67
Chilled carcass wt, lb[b]	109.09	108.53	115.31	111.95	112.46	109.28	2.90
Dressing percentage[b]	68.67	68.34	72.49	70.71	71.12	68.68	2.71
Backfat thickness, in[c]	.69	.71	.59	.53	.51	.50	11.10
Tenth rib fat depth, in[c]	.55	.61	.56	.38	.39	.46	18.66
Longissimus muscle area, in^2	4.88	4.55	5.48	5.25	5.14	5.17	7.75
Carcass length, in	28.40	28.18	28.11	27.89	28.24	27.90	1.49
Kidney fat, lb[c]	1.04	.87	.71	.57	.47	.47	27.23
Carcass composition, %							
Moisture[bc]	59.91	61.12	61.98	64.05	64.52	62.72	3.12
CP (N × 6.25)[bc]	16.71	16.99	18.76	18.37	18.10	18.10	5.37
Lipid[cd]	16.23	14.68	12.45	11.53	11.40	12.37	15.68
Ash	3.17	3.44	3.33	3.36	2.66	3.34	12.05
Quality							
Muscle score[ce]	3.61	3.29	5.70	5.08	5.20	5.36	16.55
Marbling[fg]	1.72	1.43	1.21	1.51	1.00	1.19	19.91
Color[g]	1.94	1.87	1.80	2.00	2.04	1.93	16.40
Firmness[g]	2.09	1.85	1.99	2.27	2.34	2.47	26.89

[a] Calculated from 36 pigs at a pen mean weight of 160 lb, one pig/pen, six pigs/treatment.
[b] Quadratic effect of digestible lysine (P<.05).
[c] Linear effect of digestible lysine (P<.01).
[d] Quadratic effect of digestible lysine (P<.01).
[e] Carcasses were evaluated on a six point scale ranging from thin muscling (1) to extremely thick muscling (6).
[f] Linear effect of digestible lysine (P<.05).
[g] Loins were evaluated on a five point scale according to NPPC (1991) procedures.

INFLUENCE OF DIETARY LYSINE ON GROWTH PERFORMANCE OF HIGH-LEAN GROWTH GILTS FED FROM 160 TO 300 LB[1]

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Summary

One-hundred eight high-lean growth gilts (159.6 lb) were used to determine the dietary lysine requirement to optimize growth performance from 160 to 300 lb. The experiment was designed as a randomized complete block, with initial weight serving as the blocking factor. Six dietary treatments were used, ranging from .44 to .94% digestible lysine (.59 to 1.16% total lysine). Pigs were housed in pens of three, with six replicate pens/treatment. Pig weights and feed disappearance were collected weekly to calculate average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G). Average daily gain increased from 160 to 230 lb, from 230 to 300 lb, and from 160 to 300 lb. Average daily feed intake was not influenced by dietary treatment. The gilts consumed 6.47, 6.65, and 6.56 lb/day from 160 to 230, from 230 to 300, and from 160 to 300 lb, respectively. Thus, F/G improved linearly from 160 to 230 lb and quadratically from 230 to 300 and from 160 to 300 lb as a function of increased ADG. Lysine intake was increased linearly for all three weight periods as digestible lysine increased in the diet. The data from this experiment suggest that high-lean growth gilts requires at least 26 g/d of lysine from 160 to 230 and from 230 to 300 lb. Thus, matching nutrition with genetics is essential to optimize both rate and efficiency of gain.

(Key Words: Pigs, Growth, Genotype, Gilts.)

Introduction

The National Research Council (1988) reported extensive research on dietary lysine estimates for growing-finishing swine. However, the extent of experiments pertaining to dietary lysine requirements based on protein accretion rate or carcass leanness potential is limited. Previous research conducted at Kansas State University indicated that high-lean growth gilts exhibit a greater response to dietary lysine than barrows. Therefore, gilts had a greater lean deposition rate and improved lean efficiency, even though barrows had a greater average daily gain. Similar research conducted by the NCR-42 committee on swine nutrition indicated that gilts had a greater response to increased crude protein and lysine compared to barrows in terms of rate and efficiency of lean deposition. Thus, nutritional programs based upon genetics and gender are a necessity to maximize both rate and efficiency of lean deposition. Therefore, the objective of this experiment was to determine the dietary lysine requirement to optimize growth performance and protein accretion rate for high-lean growth gilts fed from 160 to 300 lb.

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[1] We would like to acknowledge Nutri-Quest Inc. and BioKyowa Inc., St. Louis, MO, for partial financial and amino acid support for this project.

[2] Nutri-Quest, Inc., St. Louis, MO 63017.

Procedures

Animals. One hundred eight high-lean growth gilts (initially 159.6 lb) were used to determine the lysine requirement to optimize growth performance with six dietary treatments. The gilts were delivered to the Kansas State University Swine Research Center and were fed a corn-soybean meal diet containing 1.15% total dietary lysine until they reached an average weight of 160 lb. Three pigs were housed per pen (4 ft × 15 ft pens with solid flooring) in an open-fronted building with six replicate pens per treatment. The trial was conducted from May 19 to July 28, 1993, and when temperatures exceeded 80°F, drip coolers were activated to wet the pigs for 3 out of every 15 min. Each pen contained a single-hole feeder and a nipple waterer to accommodate *ad libitum* access to feed and water. Pig weights and feed disappearance were collected weekly to determine ADG, ADFI, feed efficiency (F/G), and lysine intake. When the mean weight for pigs in a pen reached 230 and 300 lb, one pig per pen was randomly selected and slaughtered.

Diet Formulation. Dietary treatments ranged from .44 to .94% digestible lysine, with total calculated dietary lysine ranging from .52 to 1.11% (Table 1). Corn-soybean meal diets were balanced to digestible lysine levels. Other amino acid levels were set using an ideal amino acid ratio to assure that lysine was the first limiting amino acid. Calculated amino acid digestibility coefficients were used for the feed ingredients. The corn-soybean meal ratio was altered to increase the dietary lysine content. L-Lysine-HCl was maintained at .05% of the complete diet, so that lysine bioavailability was not influenced by high inclusion of synthetic lysine. All diets contained 3% soybean oil. All other nutrients either met or exceeded NRC (1988) estimates for the 110 to 240 kg pig.

Results

From 160 to 230 lb, ADG was greater (linear, P<.01) as digestible lysine increased from .44 to .94%. However, ADFI was not influenced by dietary treatment. The gilts in this experiment consumed approximately 6.47 lb/day from 160 to 230 lb. Thus, the improvement (linear, P<.05) in F/G was a function of increased ADG. Lysine intake from 230 to 300 lb increased (linear, P<.01) as the percentage of dietary lysine increased. Average daily gain from 230 to 300 lb tended to be greater (quadratic, P<.10) for gilts fed increased dietary lysine. Average daily gain was maximal for gilts fed .74% digestible lysine. Average daily feed intake was not influenced from 230 to 300 lb, with all gilts consuming approximately 6.65 lb/day. Therefore, F/G tended (quadratic, P<.10) to improve as digestible lysine increased from .44 to .74% and then became poorer as digestible lysine increased to .94%. Lysine intake increased (linear, P<.01) as the percent digestible lysine increased in the diet. For the entire experiment (160 to 300 lb), ADG increased (linear, P<.13; quadratic, P<.13) as digestible lysine increased. Average daily feed intake was not influenced by dietary treatment, resulting in a tendency for improvement (quadratic, P<.10) in F/G as digestible lysine increased. Lysine intake for the entire experiment increased (linear, P<.01) as digestible lysine increased in the diet.

Discussion

The results of this experiment suggest that the high-lean growth gilt requires at least 26 g/d of lysine intake from 160 to 300 lb to optimize growth performance. These data represent a 23% increase in dietary lysine above National Research Council (1988) estimates. Unlike our research for high-lean growth gilts fed from 80 to 160 lb (p. 85), the gilts in this experiment had similar ADFI to NRC estimates (6.6 vs 6.9 lb). Thus, greater dietary lysine is necessary to support improvements in ADG and F/G.

When the gilts were fed .59% total lysine (.44% digestible lysine) from 160 to 230 lb, a 1.86 lb ADG was achieved. This is comparable to NRC estimates for both total lysine and ADG. Thus, the improvements in genetic potential are not realized if the dietary lysine requirement is not matched to genetic potential for lean tissue deposition. Similarly, F/G was improved by 7 to 10% when digestible lysine was increased from .44 to .74 or .94%, respectively. These data represent a 14% improvement above NRC estimated F/G for 160 to 230 lb pigs.

From 230 to 300 lb, ADG and F/G were improved by 13% for gilts fed .93% total lysine compared to gilts fed .59% total lysine. Again, these data suggest that genetic potential for lean deposition will not be realized if dietary lysine is not increased above NRC estimates. On the other hand, gilts fed excess dietary lysine (1.05 or 1.16% total lysine) had poorer ADG and F/G than gilts fed .93% total lysine. This poorer growth performance may reflect an increased energy expenditure to rid the body of excess amino acids not required for muscle deposition.

Thus, in summary, the results of this experiment suggest that the high-lean growth gilt requires at least 26 g/d lysine from 160 to 230 and from 230 to 300 lb. The data from this experiment suggest growth performance comparable to National Research Council estimates when the NRC recommendation for lysine (.60%) was fed. However, improvements in ADG and F/G resulted by increasing dietary lysine. Thus, matching nutrition with genetic potential will result in optimal growth performance.

Table 1. Diet Composition

	Digestible lysine, %					
Item, %	.44	.54	.64	.74	.84	.94
Corn	82.46	78.84	74.90	70.92	66.93	62.924
Soybean meal (48% CP)	10.88	14.89	18.90	22.91	26.93	30.94
Soy oil	3.00	3.00	3.00	3.00	3.00	3.00
L-lysine HCl	.05	.05	.05	.05	.05	.05
L-threonine	--	--	.008	.03	.052	.083
DL-methionine	--	--	.002	.036	.05	.119
Monocalcium phosphate (21% P)	1.66	1.58	1.51	1.44	1.37	1.30
Limestone	.96	.95	.93	.92	.90	.89
Salt	.35	.35	.35	.35	.35	.35
Trace mineral premix	.15	.15	.15	.15	.15	.15
Vitamin premix	.20	.20	.20	.20	.20	.20
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis, %						
Crude protein	12.47	14.08	15.68	17.32	18.95	20.60
Total lysine	.59	.70	.82	.93	1.05	1.16
Ca	.75	.75	.75	.75	.75	.75
P	.65	.65	.65	.65	.65	.65
Mcal/lb	1550	1550	1550	1550	1550	1550

Table 2. Effect of Increased Digestible Lysine on Growth Performance of High-Lean Growth Gilts Fed from 160 to 300 lb[a]

	Digestible Lysine, %						
Item	.44	.54	.64	.74	.84	.94	CV
ADG, lb							
160 to 230 lb[b]	1.86	1.93	1.95	1.97	2.03	2.05	7.17
230 to 300 lb[c]	1.88	1.77	1.82	2.15	2.02	1.70	14.19
160 to 300 lb[de]	1.86	1.85	1.89	2.02	2.01	1.88	7.05
ADFI, lb							
160 to 230 lb	6.54	6.24	6.45	6.43	6.67	6.49	7.74
230 to 300 lb	6.67	6.32	6.94	6.37	6.77	6.81	10.34
160 to 300 lb	6.59	6.27	6.63	6.46	6.72	6.64	7.48
F/G							
160 to 230 lb[f]	3.53	3.25	3.32	3.28	3.29	3.17	7.54
230 to 300 lb[c]	3.59	3.59	3.85	3.11	3.40	4.06	14.40
160 to 300 lb[c]	3.56	3.40	3.51	3.22	3.34	3.55	7.04
Lysine intake, g/d							
160 to 230 lb[b]	16.32	18.97	23.13	26.55	31.18	33.87	9.06
230 to 300 lb[b]	16.65	19.20	24.88	26.28	31.61	35.53	11.22
160 to 300 lb[b]	16.44	19.06	23.77	26.65	31.38	34.63	8.46

[a] A total of 108 pigs, three pigs/pen from 160 to 300 lb and two pigs/pen from 230 to 300 lb; six replicate pens/treatment.

[b] Linear effect of digestible lysine (P<.01).

[c] Quadratic effect of digestible lysine (P<.10).

[d] Linear effect of digestible lysine (P<.13).

[e] Quadratic effect of digestible lysine (P<.13).

[f] Linear effect of digestible lysine (P<.05).

THE INFLUENCE OF DIETARY LYSINE ON CARCASS CHARACTERISTICS AND SUBPRIMAL CUT DISTRIBUTION OF HIGH-LEAN GROWTH GILTS FED TO 230 AND 300 LB

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Summary

Seventy-two high-lean growth gilts were used to determine the effects of dietary lysine on carcass characteristics and subprimal cut distribution of gilts fed to 230 or 300 lb. The gilts were fed one of six lysine treatments (digestible lysine of .44, .54, .64, .74, .84, and .94% corresponding to .55, .67, .79, .91, 1.03, and 1.15% total lysine, respectively). For gilts fed to 230 or 300 lb, effects on carcass characteristics or subprimal cut distribution were minimal. For gilts fed to 230 lb, only slight linear decreases in 402 ham and boneless 402C ham were observed as dietary lysine increased. Therefore, producers can utilize a level of lysine to maximize growth performance, without negatively affecting carcass characteristics or subprimal cut yields.

(Key Words: Pork, Lysine, Gilts, Meat Yield.)

Introduction

The swine industry has been concentrating on optimizing lean pork production. Previous research has shown that high-lean growth gilts offer the largest potential for maximized lean tissue accretion and improved lean efficiency. These gilts when fed to heavier weights can also produce desirable carcasses with high subprimal cut yields. Lysine has normally been the first limiting amino acid for protein synthesis in pigs. Therefore, the objective of this study was to determine the effects dietary lysine on carcass characteristics and subprimal cut distribution of high-lean growth gilts fed to 230 or 300 lb.

Procedures

Growth performance for the gilts used in this study is discussed on page 96. One hundred eight gilts were blocked by initial weight and then allocated to one of six lysine treatments (dietary lysine of .44, .54, .64, .74, .84, or .94% which corresponds to .55, .67, .79, .91, 1.03, and 1.15% total lysine, respectively). One gilt was randomly selected and slaughtered when the pen mean weight reached 230 lb. The remaining two gilts were fed until the pen mean weight reached 300 lb. At this time, one gilt was randomly selected and slaughtered. The remaining gilt was not used in this part of the study.

Carcass characteristics were recorded at 24 hr postmortem. The left sides of the carcasses were then fabricated into closely trimmed, bone-in and boneless subprimal cuts according to National Association of Meat Purveyors (NAMP) Specifications.

Results and Discussion

Dressing percentage, USDA grade, percentage muscle, and subprimal cut yield percentages of gilts fed to 230 lb are given in Table 1. Carcass characteristics and subprimal cut percentages, except for the 402 ham and boneless 402C ham, were not influenced by dietary lysine ($P>.10$). The 402 ham and boneless 402C ham appeared to show slight linear decreases as dietary lysine increased ($P<.05$).

Gilts fed to 300 lb (Table 2) also showed no differences ($P>.10$) in subprimal cut percentages or carcass characteristics, except for the USDA grade and average backfat. The USDA grade and average backfat appeared to have a quadratic effect (P<.05), with the intermediate lysine levels giving higher values.

Even though differences in dietary lysine resulted in differences in gain and efficiency for high lean gilts fed to either 230 or 300 lb (p. 96), minimal differences in carcass traits or subprimal cut distribution were observed. Therefore, producers can focus on and use a level of lysine that can optimize growth performance, without significantly affecting carcass characteristics or subprimal cut yields.

Table 1. The Effects of Dietary Lysine on Carcass Characteristics and Subprimal Cut Distribution of Gilts Fed to 230 lb[a]

	Digestible Lysine, %[b]						
Item	.44	.54	.64	.74	.84	.94	CV
Live wt, lb	220.2	217.3	220.4	222.3	219.5	220.0	3.0
Hot carcass wt, lb	164.6	162.4	162.9	165.2	163.5	165.8	4.1
Dressing percentage, %[c]	74.8	74.7	74.0	74.3	74.5	74.7	2.1
Last rib backfat, in	.72	.75	.67	.75	.73	.76	16.1
Muscle score[d]	2.5	2.6	2.6	2.4	2.5	2.3	13.7
USDA Grade[e]	1.0	1.0	1.0	1.1	1.0	1.1	13.3
Average backfat, in	.87	.87	.89	.91	.87	.91	11.6
Carcass length, in	30.8	30.5	30.8	30.6	30.6	30.5	2.8
Tenth rib fat depth, in	.64	.73	.74	.69	.72	.74	22.9
Loin eye area, in^2	5.6	5.8	5.7	5.9	5.8	5.8	11.5
Percent muscle, %[f]	57.8	57.4	57.2	57.7	57.5	57.1	3.3
Percent lean, %[g]	53.9	53.6	53.2	53.9	53.6	53.1	5.1
Chilled side wt, lb	81.1	80.2	80.1	81.1	81.0	81.2	3.8
Hind foot, %	2.0	1.9	2.0	1.9	1.9	1.8	11.6
402 ham, %[h]	24.7	24.2	24.3	23.8	23.9	23.4	4.3
402C ham, boneless, %[h]	20.3	19.6	20.1	19.3	19.2	18.8	6.6
420 front foot, %	1.3	1.3	1.2	1.3	1.3	1.2	11.7
Jowl, %	2.2	2.2	2.3	2.1	2.4	2.3	16.6
421 neck bones, %	1.6	1.4	1.5	1.6	1.6	1.5	11.6
405 picnic shoulder, %	11.1	10.7	10.8	11.3	10.8	11.3	6.6
405A picnic shoulder, boneless, %	8.3	8.1	8.2	8.7	8.2	8.7	8.3
406 Boston butt, %	7.8	8.0	7.4	8.0	7.9	8.0	6.9
406A Boston butt, boneless, %	7.3	7.6	7.0	7.6	7.5	7.5	6.8
410 loin, %	22.5	22.1	22.2	22.1	22.1	21.6	7.1
413 loin, boneless, %	14.8	14.1	14.4	14.7	14.2	14.1	9.2
415 tenderloin, %	1.5	1.5	1.4	1.4	1.4	1.4	7.5
416 spareribs, %	3.9	4.1	4.0	3.8	3.9	4.0	6.5
408 belly, %	13.7	14.2	13.9	13.3	13.8	14.0	6.1
Boneless ham, loin and shoulder, %[i]	52.2	50.8	51.1	51.6	50.4	50.6	4.2

[a] Subprimal cut percentages are a percentage of chilled side wt.

[b] Digestible lysine of .44, .54, .64, .74, .84, and .94% correspond to .55, .67, .79, .91, 1.03, and 1.15% total lysine, respectively.

[c] Dressing percentage = (hot carcass wt, lb/live wt, lb) × 100.

[d] Muscle score: 1 = thin, 2 = average, and 3 = thick.

[e] USDA Grade = (4 × last rib backfat, in) – (1 × muscle score).

[f] Percent muscle = 100 × [10.5 + (.5 × hot carcass wt, lb) + (2.0 × loin eye area, in^2) – (14.9 × tenth rib fat depth, in)]/hot carcass wt, lb.

[g] Percent lean = 100 × [7.231 + (.437 × hot carcass wt, lb) – (18.746 × tenth rib fat depth, in) + (3.877 × loin eye area, in^2)]/hot carcass wt, lb.

[h] Linear effect of lysine ($P<.05$).

[i] 402C ham + 405A picnic shoulder + 406A Boston butt + 413 loin + 415 tenderloin.

Table 2. The Effects of Dietary Lysine on Carcass Characteristics and Subprimal Cut Distribution of Gilts Fed to 300 lb[a]

	Digestible Lysine, %[b]						
Item	.44	.54	.64	.74	.84	.94	CV
Live wt, lb	295.2	295.2	303.0	296.8	197.2	292.0	3.4
Hot carcass wt, lb	225.5	225.7	229.8	223.5	221.9	221.2	3.4
Dressing percentage, %[c]	76.4	76.5	75.8	75.3	74.7	75.8	2.1
Last rib backfat, in	.86	1.0	1.1	.89	1.1	.84	18.2
Muscle score[d]	2.6	2.7	2.7	2.6	2.5	2.5	11.4
USDA Grade[ef]	1.1	1.5	1.7	1.3	1.8	1.1	38.2
Average backfat, in[f]	1.1	1.1	1.2	1.1	1.2	1.0	12.8
Carcass length, in	33.6	33.0	33.6	33.4	33.3	34.1	2.3
Tenth rib fat depth, in	1.0	1.1	1.1	.99	1.2	.96	22.9
Loin eye area, in^2	6.4	7.2	6.6	6.7	6.7	6.3	11.8
Percent muscle, %[g]	54.1	54.1	54.0	54.5	53.5	54.5	3.6
Percent lean, %[h]	49.4	49.9	49.4	50.2	48.8	49.8	5.6
Chilled side wt, lb	111.2	112.6	113.6	111.5	109.7	109.1	3.7
Hind foot, %	1.7	1.7	1.7	1.8	1.7	1.8	7.0
402 ham, %[h]	22.4	21.4	21.9	22.0	21.5	21.6	5.2
402C ham, boneless, %	17.7	17.0	17.5	17.4	16.8	17.2	6.6
420 front foot, %	1.1	1.1	1.2	1.3	1.2	1.2	9.5
Jowl, %	2.5	2.4	2.4	2.5	2.1	2.3	14.1
421 neck bones, %	1.5	1.6	1.5	1.5	1.4	1.5	21.0
405 picnic shoulder, %	10.2	10.3	10.3	10.5	10.2	10.4	7.7
405A picnic shoulder, boneless, %	7.9	8.0	8.0	8.2	7.8	8.0	9.6
406 Boston butt, %	7.7	7.8	7.7	7.9	7.6	7.9	9.4
406A Boston butt, boneless, %	7.3	7.5	7.4	7.6	7.3	7.6	9.4
410 loin, %	21.7	21.3	21.5	20.7	20.8	21.9	6.5
413 loin, boneless, %	14.0	13.7	14.3	13.6	13.5	14.4	9.4
415 tenderloin, %	1.3	1.2	1.3	1.2	1.2	1.3	12.1
416 spareribs, %	3.9	3.7	3.8	4.0	3.7	3.9	7.5
408 belly, %	14.8	14.2	14.7	15.5	15.2	14.7	5.3
Boneless ham, loin and shoulder, %[i]	48.2	47.4	48.5	48.0	46.6	48.4	4.8

[a] Subprimal cut percentages are a percentage of chilled side wt.

[b] Digestible lysine of .44, .54, .64, .74, .84, and .94% correspond to .55, .67, .79, .91, 1.03, and 1.15% total lysine, respectively.

[c] Dressing percentage = (hot carcass wt, lb/live wt, lb) × 100.

[d] Muscle score: 1 = thin, 2 = average, and 3 = thick.

[e] USDA Grade = (4 × last rib backfat, in) – (1 × muscle score).

[f] Quadratic effect of dietary lysine ($P<.05$).

[g] Percent muscle = 100 × [10.5 + (.5 × hot carcass wt, lb) + (2.0 × loin eye area, in^2) – (14.9 × tenth rib fat depth, in)]/hot carcass wt, lb.

[h] Percent lean = 100 × [7.231 + (.437 × hot carcass wt, lb) – (18.746 × tenth rib fat depth, in) + (3.877 × loin eye area, in^2)]/hot carcass wt, lb.

[i] 402C ham + 405A picnic shoulder + 406A Boston butt + 413 loin + 415 tenderloin.

EFFECT OF METHIONINE:LYSINE RATIO ON GROWTH PERFORMANCE AND BLOOD METABOLITES OF GROWING-FINISHING PIGS[1]

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Summary

Eighty growing-finishing pigs (40 barrows and 40 gilts) were used in three consecutive growth assays to determine the optimum methionine:lysine ratio for pigs weighing from 48 to 107 lb, 120 to 179 lb, and 191 to 245 lb, respectively. Each growth assay was to be conducted for a 28-d period with a 14-d transition period between assays. Pigs were allotted by weight and placed in pens each containing one barrow and one gilt. Pigs were assigned to one of eight experimental treatments with five replicate pens per treatment. Pigs were fed diets containing either high lysine (1.0, .9, or .8%, respectively) or low lysine (.8, .7, or .6%, respectively) with dietary methionine at 24.5, 28, 31.5, or 35% of lysine. This would correspond to total sulfur-containing amino acids (methionine + cystine) of 49, 56, 63, and 70% relative to lysine. During the first study (48 to 107 lb), average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G) improved with increasing dietary lysine. Although no differences occurred in growth performance with increasing methionine ratio, there was a numeric improvement in growth performance for those pigs receiving diets containing 28% methionine relative to lysine. A lysine × methionine interaction was observed for blood urea N with pigs having the lowest BUN values observed with methionine at 24.5 and 31.5% of lysine for pigs fed .8 and 1.0% lysine, respectively. During phase II (120 lb to 179 lb), ADG improved with increasing dietary lysine and showed a linear response to increasing methionine ratio. Feed efficiency was also improved with increasing dietary lysine. For the third phase (191 to 245 lb), ADG also improved with increasing dietary lysine. There were no significant differences in feed intake; however, feed efficiency improved with increasing dietary lysine. In summary, because of high ADFI observed in these studies, the dietary methionine levels used closely met or exceeded the pig's requirement on a grams/day basis. Therefore, these data suggest that increasing dietary methionine does not improve pig performance.

(Key Words: Lysine, Methionine, Growth Performance, Growing-Finishing.)

Introduction

Previous research has attempted to determine the optimum ratio at which methionine is in accordance to lysine, which is typically the first limiting amino acid in swine diets. Recent research has suggested that the ratio may be as high as 70% total sulfur-containing amino acids, whereas others have suggested that the ratio is closer to 63%. Both of the ratios are higher than currently suggested by the ARC (1981) and NRC (1988). When attempting to determine the appropriate methionine level, most experiments have used a constant lysine level; however, the methionine requirement may be affected when the lysine level is

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[1] The authors would like to thank the Degussa Corp., Allendale, NJ for providing the amino acids used in this experiment.

changed. Also, as the pig matures, the ratio of other amino acids relative to lysine may vary. Thus, the objective of this experiment was to determine the optimum ratio of methionine to lysine for pigs weighing approximately 48 to 107 lb, 120 to 179 lb, and 191 to 245 lb and fed two levels of dietary lysine.

Procedures

Eighty Duroc × (Yorkshire × Hampshire) pigs (40 barrows and 40 gilts) were used in three consecutive growth assays to determine if the ratio of methionine to lysine changes as the lysine level of the diet is changed and as the pig matures. Pigs were allotted by weight and ancestry to pens containing 1 barrow and 1 gilt. Pigs were assigned to one of eight dietary treatments in 2 × 4 factorial design. Pigs were housed in an environmentally controlled finishing barn with ad libitum access to feed and water with a single hole feeder and one nipple waterer. Diets contained either 1.0 or .8% lysine and methionine in ratio to lysine at either 24.5, 28, 31.5, or 35%. During phase I of the experiment, pigs were started at an average initial weight of 48 lbs. Pigs were used in phase I for 28 days, at which time they were reallotted. After a 14-d adjustment period, pigs were switched to phase II of the experiment. Pigs were started on phase II at an average initial weight of 120 lbs. Pigs received diets containing either .9 or .7% lysine with methionine in ratio to lysine the same as in the first experiment. Pigs were kept on phase II of the experiment for 28-d, at which time they were again reallotted by weight and allowed a 14-d transition period before the initiation of phase III. During phase III, pigs received diets that were formulated to contain either .8 or .6% lysine with methionine in ratio to lysine in the same manner as in the first two phases. Pigs were kept on phase III of the experiment for 32-d. Pigs and feeders were weighed on d 14 and 28 of each phase to determine ADG, ADFI, and feed efficiency (F/G). Plasma samples were also taken from each pig on d 14 and 28 and analyzed for blood urea N content (BUN).

Results and Discussion

During phase I (48 to 107 lb), ADG (P<.05), ADFI (P<.01) and feed efficiency (F/G) (P<.001) showed significant responses to higher lysine diets. Pigs receiving the 1.0% lysine diet gained .10 lb/d more, consumed .20 lb/d more and were more efficient (1.86 vs 2.06) than those receiving the .8% lysine diet. There were no differences in pigs receiving the various ratios of methionine to lysine. However, there was a significant difference in BUN for each bleeding period, with significant lysine (P<.001), methionine (P<.05), and lysine by methionine (P<.002) responses for d 14 of the phase I period. Pigs receiving the diets containing .8% lysine had lower BUN than those fed 1.0% lysine. Pigs receiving the diet with methionine included at 24.5% of lysine had the lowest BUN for the .8% lysine diet, and those fed the 31.5% methionine:lysine diet for the 1.0% lysine had the lowest BUN. A similar pattern was seen for the d 28 bleeding of the phase I period. During phase II (120 to 179 lb), significant response to additional lysine and increasing methionine ratio occurred for ADG, (P<.01) and (P<.05), respectively. Pigs receiving diets containing .9% lysine gained .15 lb/d more, consumed .10 lb/d more feed, and were more efficient (2.78 vs 2.94) than those pigs receiving the .7% lysine diet. There also was a linear (P<.02) response to increasing the methionine ratio, with pigs receiving diets containing 31.5 and 35% methionine:lysine having the greatest ADG. Again, significant linear (P<.07) response in ADFI was observed for increasing methionine ratio. However, a significant response (P<.01) occurred only in feed efficiency with increased dietary lysine level. Blood urea nitrogen on d 14 and 28 increased (P<.001) with dietary lysine level and increasing methionine (P<.02), with both lysine levels having the lowest BUN value at the 24.5% level. During phase III (191 to 245 lb), ADG showed a significant improvement with increasing lysine level

(P<.001). There was also a quadratic response (P<.01) to increasing the ratio of methionine to lysine. Average daily gain decreased then increased as dietary methionine increased. No differences occurred in ADFI for the phase III period. However, feed efficiency was improved with increasing lysine level (P<.01). There was also a quadratic response (P<.03) in F/G, following a similar pattern to that of ADG. Blood urea nitrogen during the third phase was significantly increased (P<.001) with increasing lysine. For the third phase of the experiment, the lowest BUN was found for those pigs receiving the 28% methionine:lysine diet regardless of dietary lysine. In summary, because of high ADFI observed in these studies, the dietary methionine levels used closely met or exceeded the pig's requirement on a grams/day basis. Therefore, these data suggest that increasing dietary methionine does not improve pig performance.

Table 1. Composition of Basal Diets

	Dietary Lysine, %[a]				
Item, %	.6	.7	.8	.9	1.0
Corn	83.33	90.97	74.99	82.41	77.99
Soybean meal, 48% CP	-	1.07	8.61	9.90	14.43
Soybean oil	3.00	3.00	3.00	3.00	3.00
Monocalcium P, 21% P	1.98	1.85	1.83	1.69	1.61
Limestone	.94	.99	.91	.96	.94
Salt	.35	.35	.35	.35	.35
Vitamin premix	.20	.20	.20	.20	.20
Trace mineral premix	.15	.15	.15	.15	.15
Sugar[b]	8.84	.06	8.84	.075	.09
L-lysine-HCl	.46	.51	.41	.45	.422
Antibiotic[c]	.25	.25	.25	.25	.25
Choline chloride	.10	.10	.10	.10	.10
Cystine	.055	.096	.078	.085	.097
L-tryptophan	.067	.078	.053	.063	.06
L-isoleucine	.087	.096	.058	.064	.056
L-threonine	.16	.18	.18	.20	.205
Valine	.063	.063	.047	.054	.052
Total	100.00	100.00	100.00	100.00	100.00
<u>Calculated analysis, %</u>					
Digestible lysine	.50	.58	.67	.75	.84
Digestible methionine	.13	.14	.16	.18	.20
CP	7.25	8.43	10.25	11.9	13.8
Ca	.75	.75	.75	.75	.75
P	.65	.65	.65	.65	.65

[a] Pigs received 1.0 and .8% lysine diets (48 to 107 lb), .9 and .7% lysine diets (120 to 179 lb), .8 and .6% lysine diets (191 to 245 lb).

[b] Sugar was replaced by DL-methionine to provide the respective dietary methionine levels.

[c] Provide 50 g/ton Aureomycin.

Table 2. Effect of Methionine:Lysine Ratio on Growth Performance in Growing-Finishing Pigs Fed from 48 to 245 lb[a]

	Low Lysine[b]				High Lysine[c]				
Item	49	56	63	70	49	56	63	70	CV
<u>48 to 107 lb</u>									
ADG, lb[d]	2.05	2.12	1.90	2.14	2.21	2.23	2.10	2.08	7.77
ADFI, lb[e]	4.16	4.30	4.00	4.37	4.06	3.98	4.03	3.91	5.60
F/G[e]	2.03	2.04	2.12	2.05	1.84	1.79	1.93	1.89	6.52
<u>120 to 179 lb</u>									
ADG, lb[ef]	1.88	2.02	2.12	2.13	2.12	2.14	2.31	2.16	8.34
ADFI, lb[g]	5.72	5.79	6.27	6.06	5.94	6.00	6.39	5.98	6.23
F/G[e]	3.05	2.88	2.96	2.85	2.81	2.81	2.76	2.76	6.17
<u>191 to 245 lb</u>									
ADG, lb[eh]	1.85	1.45	1.65	1.70	1.98	1.75	1.99	1.98	10.71
ADFI, lb	6.78	6.45	6.40	6.34	6.80	6.49	6.71	6.92	9.10
F/G[ei]	3.67	4.50	3.95	3.75	3.42	3.77	3.36	3.51	11.51

[a] Eighty (40 barrows and 40 gilts) were used with 2 pigs/pen, 10 pens/treatment.

[b] Lysine levels used were .8% (48 to 107 lb),.7% (120 to 179 lb), and .6% (191 to 245 lb).

[c] Lysine levels used were 1.0% (48 to 107 lb),.9% (120 to 179 lb),and .8% (191 to 245 lb).

[d] Lysine response P<.05.

[e] Lysine response P<.01.

[f] Linear effect of methionine P<.02.

[g] Linear effect of methionine P<.07.

[h] Quadratic effect of methionine P<.01.

[i] Quadratic effect of methionine P<.03.

Table 3. Effect of Methionine:Lysine Ratio on Blood Urea Nitrogen in Growing-Finishing Pigs Fed from 48 to 245 lbs

	Low Lysine				High Lysine				
Item	49	56	63	70	49	56	63	70	CV
48 to 107 lb									
d 14 BUN[abcd]	3.7	4.2	5.6	4.6	17.3	12.2	8.7	11.1	32.7
d 28 BUN[ad]	3.4	4.5	7.1	5.6	15.9	14.6	11.1	14.2	30.2
120 to 179 lb									
d 14 BUN[acd]	6.3	17.7	7.4	7.4	16.9	17.4	18.9	21.8	28.5
d 28 BUN[ac]	8.8	19.4	12.3	10.3	20.8	22.8	21.8	20.7	27.1
191 to 245 lb									
d 14 BUN[a]	12.6	11.1	13.1	10.9	20.8	16.7	19.8	19.4	15.0
d 28 BUN[a]	11.7	7.7	9.5	9.4	16.8	14.5	16.2	14.7	24.9

[a] Lysine response P<.001.
[b] Linear effect of methionine P<.01.
[c] Quadratic effect of methionine P<.10.
[d] Lysine × methionine interaction P<.01.

THE INFLUENCE OF THREONINE:LYSINE RATIOS ON GROWTH PERFORMANCE AND ON PLASMA UREA NITROGEN IN GROWING-FINISHING PIGS FED FROM 85 TO 240 LB

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Summary

Eighty crossbred pigs (initially 85.2 lb BW) were used in a 2 × 4 factorial arrangement to determine the influence of dietary threonine:lysine ratios on growth performance and plasma urea N in growing-finishing pigs. The experiment was conducted in three phases from 85.2 to 124.2, 139.1 to 203.1, and 204.9 to 241.1 lb, with pigs fed one of eight dietary treatments. Two levels of dietary lysine were fed (low vs high) and four levels of dietary threonine were fed within each lysine treatment (60, 65, 70, and 75% of dietary lysine). Dietary lysine decreased from 1.0% and .8% at 85.2 to 124.2 lb to .9 and .7% at 139.1 to 203.1, then to .7 and .5% at 204.9 to 241 1 lb. Average daily gain (ADG) and feed efficiency (F/G) were not influenced by lysine or threonine treatment from 85.2 to 124.2 lb. However, average daily feed intake was decreased for pigs fed 1.0% dietary lysine compared to .8% dietary lysine. From 139.1 to 203.1 lb, an interaction between dietary lysine and threonine existed for ADG. Average daily gain was maximized at 65 and 70% of dietary lysine for pigs fed .7 and .9% dietary lysine, respectively. Conversely, ADFI and F/G were not influenced by threonine:lysine ratios. From 204.9 to 241.1 lb, ADG and ADFI were not influenced by dietary treatment. However, F/G was improved for pigs fed .7% dietary lysine compared to pigs fed .5% dietary lysine. Plasma urea N was increased at 124.2 and at 203.1 for pigs fed greater dietary lysine. At 241.1 lb, plasma urea N was decreased linearly at the percentage of threonine increased from 60 to 75% of lysine. The data from this experiment indicate that excess lysine and threonine intakes do not decrease growth performance. Because high ADFI resulted in high amino acid intake, growth performance was not influenced by the amino acid ratios used in this experiment.

(Key Words: Pigs, Lysine, Threonine, Growth Performance.)

Introduction

Previous research at Kansas State University has suggested that the dietary threonine requirement for growing pigs is greater than current NRC (1988) estimates. Our data suggest that the 70 lb pig requires at least .50 to .60% (10 to 11 g/d) dietary threonine to maximize growth performance. These data represent a 13% increase in dietary threonine compared to NRC estimates. Similar results have been reported from the University of Kentucky and Georgia for the growing pig. Results from the University of Illinois suggest that the ideal ratio of threonine to lysine is 70% of the dietary lysine content. If these data are correct, current NRC estimates would slightly underestimate the threonine requirement for growing-finishing pigs. Thus, the objective of this experiment was to determine the dietary threonine requirement relative to lysine for pigs fed from 85 to 240 lb.

Procedures

Animals. Eighty Duroc × (Yorkshire × Hampshire) pigs (40 barrows and 40 gilts) with an 85.2 lb initial BW were used in a 2 × 4 factorial arrangement. The experiment was conducted in three phases and designed as a randomized complete block, using initial BW as the blocking factor for each of the three phases. Pigs (one barrow and one gilt) were housed in an environmentally controlled finishing barn with total slatted flooring (4 ft × 4 ft pens) with five replicate pens per treatment. Each pen contained a single-hole self-feeder and a nipple waterer to provide *ad libitum* access to feed and water. Drip coolers were activated when temperatures exceeded 80°F, cycling on for 3 out of every 15 min. Pig weights and feed disappearance were recorded weekly to determine ADG, ADFI, and feed efficiency (F/G). The first experiment (85 to 124 lb) was conducted for 18 d. At the end of the experiment, pigs were reallotted based upon final BW and given a 7 d adjustment period. This same procedure was followed at the end of the second experiment (139 to 203 lb). Pig weights and feed disappearance were collected weekly to calculate average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G).

Diets. The experiment was conducted in three separate phases. Diets were formulated on a digestible lysine basis (Table 1), using a 65% ratio of isoleucine, a 70% ratio of methionine + cystine, a 20% ratio of tryptophan, and a 68% ratio of valine to ensure that threonine would be first limiting. From 85 to 124 lb, pigs were fed either a 1.0 or a .8% total dietary lysine diet, with threonine being either 60, 65, 70, or 75% of lysine. Dietary lysine was decreased to .9 and .7% and to .7 and .5% from 139 to 203 lb and from 205 to 241 lb, respectively. The diets contained .65% Ca and .5% P, with all other nutrients formulated in excess of NRC estimates.

Plasma Urea N. Plasma samples were taken at the end of each growth phase (124, 203, and 241 lb) and analyzed for urea N content. Samples for analysis were taken from both pigs in a pen and pooled to give a pen mean urea N concentration.

Results and Discussion

Growth Performance. From 85.2 to 124.2 lb (Table 1), ADG (P>.10), ADFI (P>.10), and F/G (P>.10) were not influenced by the threonine:lysine ratio. Lysine intake was increased (P<.01) for pigs fed 1.0% dietary lysine compared to pigs fed .80% dietary lysine. Threonine intake increased (P<.01) for pigs fed 1.0 vs .80% dietary lysine. Within lysine treatment, threonine intake increased (quadratic, P<.10; linear, P<.10) as the threonine: lysine ratio increased.

Average daily gain from 139.1 to 203.1 lb showed an interactive effect (P<.05) between dietary lysine and threonine. Pigs fed .70% dietary lysine had optimal ADG when a 70% threonine:lysine ratio was fed. Conversely, pigs fed .90% dietary lysine had optimal ADG when a 65% threonine:lysine ratio was fed. Average daily feed intake (P>.10) and F/G (P>.10), however, were not influenced by the threonine:lysine ratio. Lysine intake was greater (P<.01) for pigs fed .90% dietary lysine compared to pigs fed .70% dietary lysine. Similarly, threonine intake was increased (P<.01) for pigs fed greater dietary lysine. Within lysine treatment, threonine intake increased (linear, P<.01) as the ratio of threonine to lysine increased.

From 204.9 to 241.1 lb, neither ADG (P>10) nor ADFI (P>.10) were influenced by dietary treatment. However, F/G showed an interactive effect (P<.10) between dietary lysine and threonine. Feed efficiency for pigs fed .50% dietary lysine was optimized at a 65% threonine:lysine ratio. However, when .70% dietary lysine was fed, a 70% threonine:lysine ratio was required to optimize F/G. Feed efficiency was improved (P<.05) by increasing dietary lysine from .50 to .70%. Lysine and threonine intake were greater (P<.05) for pigs fed .70 vs .50% dietary lysine. Within lysine treatment, threonine intake increased (linear, P<.01) as the threonine:lysine ratio increased.

Plasma Urea N. Plasma urea N was

greater (P<.01) from 85.2 to 124.2 and from 139.1 to 203.1 lb for pigs fed greater dietary lysine. From 204.9 to 241.1 lb, plasma urea N was decreased (linear, P<.05) as the threonine:lysine ratio increased. Plasma urea N was numerically minimized at 65% threonine:lysine for both lysine treatments.

The results from this experiment do not indicate a strong relationship between dietary threonine:lysine ratios from 85.2 to 124.2 and 139.1 to 203.1 lb. Potentially, the lack of relationship can be explained by excess threonine and lysine intakes. Threonine intakes were 3 to 8 and 1 to 6 g/d in excess of NRC estimates for the 44 to 110 lb pig. Previous research from Europe and the University of Illinois suggests that excess amino acid intake will not result in poorer growth performance. However, diets formulated at 200% of the dietary lysine requirement will impair ADG and F/G (Oklahoma State University).

The lack of response to dietary lysine in this experiment suggests that the lysine requirement is being adequately met by the low lysine diet for each phase of the experiment. Average daily gain from 139.1 to 203.1 lb showed an interactive effect between dietary threonine and lysine. It appears that the dietary threonine requirement is potentially greater (70 vs 60% threonine:lysine, respectively) in this instance for pigs fed greater dietary lysine.

From 204.9 to 241.1 lb, dietary threonine intakes were below NRC estimates by 4 to 5 and 1 to 2 g/d for the low and high lysine diets, respectively. However, this did not affect ADG or F/G. Conversely, increasing dietary lysine resulted in improved F/G. Thus, the results from this experiment indicate that the high ADFI achieved in this experiment negated any potential relationship between dietary threonine dietary lysine and relative to ADG and F/G.

Table 1. Composition of Basal Diets

	Dietary Lysine, %				
Item, %	.5[a]	.7[ab]	.8[c]	.9[b]	1.0[c]
Corn	90.91	82.83	78.75	74.68	70.61
Soybean meal, 48% CP	2.21	10.50	14.65	18.80	22.96
Soybean oil	3.00	3.00	3.00	3.00	3.00
Monocalcium P (18% P)	1.82	1.67	1.59	1.52	1.44
Limestone	.99	.96	.94	.93	.91
Salt	.35	.35	.35	.35	.35
Vitamin premix	.20	.20	.20	.20	.20
Trace min. premix	.15	.15	.15	.15	.15
Sugar	.07	.08	.10	.11	.13
L-lysine-HCl	.270	.215	.198	.170	.151
L tryptophan	.035	.029	.018	.017	.016
DL methionine		.023	.048	.072	.087
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
CP (N × 6.25), %	8.98	12.32	14.00	15.69	17.36
Threonine, %	.37	.50	.56	.63	.69
Digestible Threonine, %	.25	.35	.40	.45	.50
Digestible Lysine, %	.42	.58	.67	.75	.84
Ca. %	.75	.75	.75	.75	.75
P, %	.65	.65	.65	.65	.65
ME, mcal/lb	1545	1545	1545	1545	1545

[a]Diets fed from 204.9 to 241.1 lb. [b]Diets fed from 139.1 to 203.1 lb. [c]Diets fed from 85.2 to 124.2 lb.

Table 2. Effect of Threonine:Lysine Ratios on Growth Performance in Growing-Finishing Pigs Fed from 85 to 240 lb[a]

	Low[b]				High[c]				
	60[d]	65	70	75	60	65	70	75	CV
85.2 to 124.2 lb									
ADG, lb	2.13	2.23	2.14	2.23	2.18	2.12	2.20	2.13	5.97
ADFI, lb[e]	5.22	5.17	5.01	5.79	5.02	4.81	5.03	5.08	9.03
F/G	2.24	2.32	2.35	2.60	2.30	2.26	2.29	2.38	10.87
Lys I, g[fg]	18.98	18.76	18.16	20.99	22.76	21.81	22.81	23.08	12.43
Thr I, g[egh]	11.37	12.19	12.71	15.73	13.66	14.18	15.97	17.32	12.51
139.1 to 203.1 lb									
ADG, lb[i]	2.34	2.14	2.44	2.36	2.26	2.47	2.27	2.21	8.19
ADFI, lb	6.77	6.32	6.93	7.04	6.89	7.02	6.78	6.45	8.72
F/G	2.90	2.96	2.84	2.99	3.06	2.86	2.98	2.92	7.23
Lys I, g[f]	21.49	20.07	22.02	23.36	28.15	28.66	27.67	26.34	8.65
Thr I, g[fj]	12.89	13.05	15.41	16.77	16.89	18.63	19.37	19.75	8.94
204.9 to 241.1 lb									
ADG, lb	1.71	1.69	1.83	1.92	1.81	1.90	2.27	1.68	15.28
ADFI, lb	5.07	5.02	5.50	5.13	5.14	5.33	5.40	4.87	10.32
F/G[ek]	3.16	3.07	3.05	2.82	2.85	2.86	2.43	2.97	10.52
Lys I, g[e]	11.51	11.40	12.47	11.64	16.33	16.92	17.09	15.48	10.16
Thr I, g[ej]	6.91	7.41	8.73	7.82	9.80	11.00	11.97	11.60	10.18

[a] Means calculated from 80 pigs, two pigs/pen, five pens/treatment.

[b] Low lysine equals .80% from 85.2 to 124.2 lb, .70% from 139.1 to 203.1 lb, and .50% from 204.9 to 241.1 lb.

[c] High lysine equals 1.00% from 85.2 to 124.2 lb, .90% from 139.1 to 203.1 lb, and .70% from 204.9 to 241.1 lb.

[d] Percentage of threonine relative to lysine.

[e] Dietary lysine effect (P<.05).

[f] Dietary lysine effect (P<.01).

[g] Quadratic effect of dietary threonine (P<.10).

[h] Linear effect of dietary threonine (P<.10).

[i] Dietary lysine × threonine effect (P<.05).

[j] Linear effect of dietary threonine (P<.01).

[k] Dietary lysine × threonine effect (P<.10).

Table 3. The Effect of Threonine:Lysine Rations on Plasma Urea N in Growing-Finishing Pigs Fed from 85 to 240 lb[a]

	Low[b]				High[c]				
Item, mg/dL	60[d]	65	70	75	60	65	70	75	CV
85.2 to 124.2 lb[e]	11.82	10.78	10.58	11.20	15.43	15.09	16.85	15.87	17.36
139.1 to 203.1 lb[e]	10.85	10.58	12.78	11.79	15.95	15.25	15.84	12.53	16.72
204.9 to 241.1 lb[f]	10.67	8.86	9.08	8.36	11.71	9.48	9.56	9.65	23.05

[a] Means calculated from 80 pigs, two pigs/pen, five pens/treatment.

[b] Low lysine equals .80% from 85.2 to 124.2 lb, .70% from 139.1 to 203.1 lb, and .50% from 204.9 to 241.1 lb.

[c] High lysine equals 1.00% from 85.2 to 124.2 lb, .90% from 139.1 to 203.1 lb, and .70% from 204.9 to 241.1 lb.

[d] Percentage of threonine relative to lysine.

[e] Dietary lysine effect (P<.01).

[f] Linear effect of dietary threonine (P<.05).

EFFECTS OF APPLICATION OF WATER AND NITROGEN ON NUTRIENT USE FROM CORN AND SORGHUMS BY PIGS

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Summary

An experiment was conducted to determine the effects of growing conditions on nutrient yield and quality of corn and sorghum. Main effect treatments were: corn (C), bronze pericarp heterozygous-yellow endosperm sorghum (BS), and yellow pericarp homozygous-yellow endosperm sorghum (YS); optimal irrigation (I) and minimal irrigation (MI); 100 lb/acre of N fertilization (F) and no N fertilization (NF), in a 3 × 2 × 2 factorial arrangement. Grains were grown in 1988 (Year 1, with little rainfall) and 1989 (Year 2, with above average rainfall) in the semi-arid environment at Garden City, KS. In Year 1, sorghums yielded 15% more grain than C, and YS yielded 1.2% more grain than BS. Irrigation increased yield by 90%, and N application increased yield by 7%. In year 2, C yielded 11% more grain than the sorghums. In the pig metabolism study, C had greater nitrogen digestibility (ND) than sorghums in both years, greater biological value (BV) and nitrogen retention in Year 2, but lower BV in Year 1. Yellow sorghum had greater ND than BS in Year 1. Corn had increased cost per unit of utilizable nitrogen (CUN) and utilizable energy (CUE) and reduced utilizable nitrogen per inch of available water (UNW) and utilizable energy per inch of available water (UEW) for both years compared to BS and YS. In conclusion, optimally irrigated grains had higher nutritional value than minimally irrigated grains, and growing the grains under varying agronomic conditions did affect their nutritional quality.

(Key Words: Corn, Sorghum, Irrigation, Fertilization, Digestibility.)

Introduction

Research indicates great variation in nutritional value of sorghum, with feeding value ranging from < 90 to > 100% that of corn. Also, reports have been conflicting of the effects of seed coat color and endosperm type on nutrient digestibility in sorghums. Other research has demonstrated that irrigation and N fertilization will increase yield of grains, but the effects of these agronomic inputs on nutritional value are not well understood. It is known that irrigation increases yield, but irrigation also may reduce CP concentration of grain. Nitrogen application is needed to maximize yields and may correct the reduction in CP content of irrigated grains. Thus, agronomic inputs that increase yield of a grain may or may not benefit its nutritional value.

The need to understand the consequences of agronomic practices on corn and sorghum as food and feed led to the research discussed herein. The objective was to determine the nutritional value of corn and two sorghum varieties in response to irrigation and N application.

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Procedures

A commercial corn hybrid (C; Dekalb 656); a bronze pericarp, heterozygous-yellow endosperm sorghum (BS; Pioneer 8515); and a yellow pericarp, homozygous-yellow endosperm sorghum (YS; Dekalb 41Y) were grown on a Richfield silt loam soil at the Southwest Research and Extension Center, Garden City, KS, in 1988 and 1989. Preplanting irrigations of 5 and 6 in were applied to all treatments in 1988 and 1989, respectively (Table 1). The years were greatly different in rainfall, with 9.7 in for 1988 and 21.1 in for 1989. Additional water was applied to give treatments of optimal irrigation (I) and minimal irrigation (MI) for corn and the sorghums. These grains were grown with (F) or without (NF) 100 lb/acre N from ammonium nitrate granules. Thus, the overall treatment arrangement was a 3 × 2 × 2 factorial with main effects of grain type (C vs BS vs YS), amount of water application (I or MI), and N application (F or NF).

In the swine metabolism experiment, 24 pigs (averaging 114 lb body wt) were used to determine apparent digestibilities of dry matter (DM), nitrogen (N), and gross energy (GE) for the experimental grains. The basal diet was formulated to 14% CP, .66% Ca, and .55% P using the grain with the lowest CP concentration (Table 2). Other grains were substituted on an equal weight basis for the grain in the first diet. The daily feed allowance was $.05 \times BW^{.9}$, offered as equal feedings at 7 a.m. and 5 p.m. For Year 1 grain, the pigs were randomly assigned to the 12 grain treatments for a 6-d adjustment period and 4-d total collection of urine, feces, and orts. The pigs were reassigned for another adjustment and collection period with the restriction that no pig could be given the same treatment twice. This procedure was replicated five times. The same protocol was used for Year 2 grain, with the exception that the adjustment period was only 4 d. Urine samples were collected once daily and acidified with 120 ml of 10% HCl; a 5% subsample was frozen. Feces and orts were collected once daily and frozen. Apparent DM and N digestibilities, biological value (BV), N retention, DE, and ME were calculated.

Results and Discussion

In Year 1, the sorghums yielded 15% more grain than C, and YS yielded 1.2% more grain than BS (Table 3). Irrigation increased yield by 90%, and N application increased yield by 7%. Irrigation increased yield of YS more than C and BS (114, 89, and 70%, respectively). In year 2, C yielded 11% more grain than the sorghums. This was likely because of greater rainfall making growing conditions more favorable for production of C in Year 2 compared to Year 1. Yellow sorghum yielded 2% more grain than BS. Irrigation increased grain yield by 18%, and N fertilizer increased yield by 10%. Yellow sorghum responded most to I with a 38% increase in yield, C was intermediate (12% increase), and BS had the least response, (8% increase). Bronze sorghum responded most to F with a 24% increase in yield, and C and YS had moderate increases of 6 and 2%, respectively.

Irrigation has been shown by other researchers to increase grain yield, but increased available water tends to decrease grain CP concentration. In contrast with irrigation, N application increases both grain yield and grain CP concentration. However, the increased protein content is primarily because of greater synthesis of zein, which is practically devoid of lysine and of poor nutritional value. Similar responses to I (i.e., increased grain yield and decreased CP concentration) were observed in the experiments reported herein. Fertilization with N gave a slight and consistent increase in grain yield. However, F did not give consistent increases in percentage CP of the grains in Year 1. This may have been caused by the low water availability and its limiting effect on plant growth and response to F.

With the improved growing conditions of Year 2, yield of the grains were more similar among treatments. However, yield still was increased with I and F, and I decreased CP percentage of the grains. Nitrogen fertilization increased grain CP concentration, with more effect on I than MI grain.

In the pig metabolism experiment, no differences occurred among treatments for DM digestibility in Year 1 or 2 (Tables 4 and 5). Corn had greater (P<.001) N digestibility in both Year 1 and 2 compared to BS and YS. Corn had reduced (P<.03) biological value (BV) when grains were grown under dry conditions (Year 1) compared to BS and YS, but had greater BV (P<.02) and N retention (P<.001) under the more ideal growing conditions of Year 2. The YS had greater N digestibility (P<.02) than BS for Year 1, but they were not different in N retention (P>.10).

Irrigation of the grains increased BV (P<.07) and N retention (P<.06) for both years, with a greater response in Year 2. Fertilizer application decreased BV (P<.01) and N retention (P<.003) for the sorghums, but increased BV and N retention for the C when the grains were grown under the more ideal conditions of Year 2. This would indicate that the sorghums had excess N fertilizer and were using it to increase prolamin synthesis in the grains, but corn was below its maximum growth potential and was using the N fertilizer for synthesis of high quality proteins (e.g., albumins or globulins). Irrigation caused a slight decrease in DE (P<.04) and ME (P<.05) for Year 2 but had no effect in Year 1. This is opposite of what was expected; more available water should have increased energy concentrations of the grains because of increased starch filling.

The calculation of utilizable energy per acre (UE = ME × grain yield) indicated many interactions among main effects due more to grain yield responses than differences in nutritional effects. Sorghums had greater UE (P<.001) under dry growing conditions (Year 1), and C had greater UE (P<.001) under the more ideal growing conditions of Year 2. Irrigation (P<.001) and F (P<.001) applications increased UE in both years.

In a review of the economic analyses for producing grains under these varying agronomic conditions (Table 6), sorghums proved more economical under the dry conditions of Year 1, and on the average for both years, were the most profitable crops. The cost of additional irrigation to corn in this environment resulted in decreased profitability. Bronze sorghum-MI under both F treatments proved the most stable economically, with YS-I under either F treatment being a close second.

In an attempt to determine the cost per unit of nutrient and evaluate water utilization efficiencies of the grains under these different growing conditions, cost per utilizable nitrogen (CUN), cost per utilizable energy (CUE), utilizable nitrogen per inch of available water (UNW), and utilizable energy per inch of available water (UEW) were calculated from the pig digestibility trial (Table 7). Corn had increased cost per unit of utilizable N and energy (P<.001) and reduced utilizable N and energy per inch of available water (P<.001) for both years compared to BS and YS. This relates to the more efficient use of water and N associated with the sorghum plant compared to corn. Irrigation decreased CUN (P<.001) and CUE (P<.001) and increased UNW (P<.001) and UEW (P<.001) in pigs for Year 1, but increased CUN (P<.001) and CUE (P<.001) and decreased UNW (P<.001) and UEW (P<.001) in Year 2 when growing conditions were more ideal and irrigation had less effect on crop production. Fertilizer application decreased CUE (P<.001) and increased UEW (P<.001) for both years. The UNW (P<.001) for Year 2 in swine was increased by F.

Considering the holistic view of grain production and animal use of these grains, the most important factor is grain yield.

Grains should be grown that have high stability for their growing environment. This was evident because in Year 1 (extremely dry), the sorghums yielded more nutrients per acre than C, but in Year 2 (a wet year), C yielded more nutrients per acre than BS and YS. Considering both years, BS gave more consistent yield of nutrients and appeared to be a more stable crop for this semi-arid region of Kansas.

This research indicated that C had increased digestibility compared to the sorghums. Yellow sorghum, with homozygous-yellow endosperm, had increased nutrient digestibility and N retention compared to BS with heterozygous-yellow endosperm. Irrigated grains were of greater nutritional value, as well as having greater yields. Given these results, for irrigating grain in a semi-arid region and feeding it to monogastric livestock, YS would be the crop of choice. For growing grain in areas with greater rainfall, the increased yield of digestible nutrients by C would make it the crop of choice. In uncertain dryland production systems, the stability of nutrient yield by the BS would make it the grain of choice. Lastly, BS-MI was the most profitable across the variable environment of both years.

Table 1. Moisture Supplied to the Grain Crops, inches[a]

Item	C-I	C-MI	S-I	S-MI
Year 1				
Preplant irrigation	5.0	5.0	5.0	5.0
Irrigation	21.0	6.0	9.0	0
Rainfall	9.7	9.7	9.7	9.7
Total	35.7	20.7	23.7	14.7
Year 2				
Preplant irrigation	6.0	6.0	6.0	6.0
Irrigation	12.0	8.0	12.0	0
Rainfall	21.1	21.1	21.1	21.1
Total	39.1	35.1	39.1	27.1

[a] C = corn, S = sorghum, I = optimal irrigation, and MI = minimal irrigation.

Table 2. Diet Composition for the Pig Metabolism Experiment, %[a]

Item	Year 1	Year 2
Grain source	82.70	80.24
Soybean meal	14.50	16.96
Monocalcium phosphate	1.08	1.08
Limestone	1.02	1.02
Salt	.30	.30
Selenium premix[b]	.05	.05
Trace mineral premix[b]	.10	.10
Vitamin premix[b]	.25	.25
Total	100	100

[a] All diets were formulated to 14% CP, .66% Ca, and .55% P.
[b] Old KSU selenium, vitamin, and mineral premixes.

Table 3. Effects of Irrigation and Nitrogen Fertilizer on Grain Yield and Chemical Composition[a]

	Year 1			Year 2		
Item	Yield, lb/acre	CP, %	GE, kcal/lb	Yield, lb/acre	CP, %	GE, kcal/lb
C-I-F[b]	6,057	9.9	1,764	7,514	7.8	1,991
C-I-NF	5,754	8.9	1,799	7,228	7.7	2,025
C-MI-F	3,300	9.3	1,769	6,852	8.5	1,987
C-MI-NF	2,958	9.6	1,778	6,320	8.9	2,001
BS-I-F	6,657	10.1	1,760	7,514	10.6	1,983
BS-I-NF	6,382	10.1	1,765	5,396	8.4	1,984
BS-MI-F	4,051	9.8	1,766	6,286	11.3	1,991
BS-MI-NF	3,631	9.8	1,790	5,704	11.0	2,010
YS-I-F	7,480	8.8	1,754	7,565	9.1	1,974
YS-I-NF	6,813	8.8	1,775	7,116	8.3	1,996
YS-MI-F	3,413	9.0	1,745	5,205	10.2	1,966
YS-MI-NF	3,266	8.9	1,734	5,419	10.4	1,951

[a] All values on an as is basis. Yield=grain yield.

[b] C = corn, BS = bronze sorghum, YS = yellow sorghum, I = optimal irrigation, MI = minimal irrigation, F = N fertilized, and NF = no N fertilizer.

Table 4. Effect of Irrigation and Nitrogen Fertilizer on Nutrient Utilization in Pigs (Year 1)[a]

Item[b]	DMD, %[c]	ND, %[c]	BV, %[c]	NR, %[c]	DE, kcal/lb[c]	ME, kcal/lb[c]	UE, Gcal/acre[c]
C-I-F	89.1	84.1	52.2	44.0	1,560	1,521	9.2
C-I-NF	89.1	83.9	53.8	45.3	1,540	1,503	8.7
C-MI-F	89.7	82.8	47.5	39.4	1,593	1,559	5.2
C-MI-NF	88.1	82.2	41.5	34.3	1,512	1,467	4.3
BS-I-F	88.8	79.8	49.8	39.6	1,543	1,500	10.0
BS-I-NF	88.4	77.5	51.8	40.2	1,543	1,509	9.6
BS-MI-F	89.3	78.6	49.9	39.5	1,557	1,532	6.2
BS-MI-NF	88.7	77.2	56.0	43.3	1,557	1,527	5.5
YS-I-F	90.7	83.0	53.4	44.2	1,579	1,523	11.4
YS-I-NF	89.2	79.0	57.3	45.1	1,544	1,514	10.3
YS-MI-F	89.1	80.0	51.9	41.2	1,551	1,516	5.2
YS-MI-NF	89.5	81.6	52.3	42.7	1,546	1,519	5.0
Contrasts and Probabilities							
C vs S	—[d]	.001	.03	—	—	—	.001
BS vs YS	—	.02	—	—	—	—	.06
I	—	—	.07	.06	—	—	.001
C vs S × I	—	—	.03	.03	—	—	.001
BS vs YS × I	—	—	—	—	—	—	.001
F	—	—	—	—	.03	—	.001
C vs S × F	—	—	—	—	.08	.03	—
BS vs YS × F	—	—	—	—	—	—	—
I × F	—	—	—	—	—	—	—
C vs S × I × F	—	—	—	—	—	—	.04
BS vs YS × I × F	—	—	—	—	—	—	.001
SE	.8	1.5	3.0	2.6	17	18	.1

[a] Five pigs/treatment.

[b] C = corn, BS = bronze sorghum, YS = yellow sorghum, S = sorghums (BS+YS), I = optimal irrigation, MI = minimal irrigation, F = N fertilized, and NF = no N fertilizer.

[c] DMD = DM digestibility, ND = N digestibility, BV = biological value, NR = N retention, DE = digestible energy, ME = metabolizable energy, and UE = utilizable energy (ME × grain yield).

[d] Dashes indicate P>.10.

Table 5. Effect of Irrigation and Nitrogen Fertilizer on Nutrient Utilization in Pigs (Year 2)[a]

Item[b]	DMD, %[c]	ND, %[c]	BV, %[c]	NR, %[c]	DE, kcal/lb[c]	ME, kcal/lb[c]	UE, Gcal/acre[c]
C-I-F	89.0	85.0	61.4	52.1	1,554	1,505	11.3
C-I-NF	88.1	83.6	57.3	47.8	1,555	1,513	10.9
C-MI-F	88.1	83.2	51.7	43.0	1,537	1,519	10.4
C-MI-NF	88.5	83.8	46.5	39.0	1,554	1,512	9.6
BS-I-F	86.9	77.7	52.3	40.6	1,578	1,547	11.6
BS-I-NF	87.9	78.7	54.2	42.5	1,588	1,548	8.4
BS-MI-F	88.6	77.4	41.9	32.2	1,600	1,556	9.8
BS-MI-NF	88.6	78.7	47.3	37.0	1,616	1,578	9.0
YS-I-F	85.7	73.7	45.6	32.6	1,541	1,509	11.4
YS-I-NF	88.5	81.7	52.7	43.1	1,588	1,550	11.0
YS-MI-F	88.6	82.3	50.3	41.5	1,615	1,579	8.2
YS-MI-NF	87.4	79.9	53.7	42.9	1,594	1,549	8.4
Contrasts and Probabilities							
C vs S	—[d]	.001	.02	.001	.001	.001	.001
BS vs YS	—	—	—	—	—	—	—
I	—	—	.003	.007	.04	.05	.001
C vs S × I	—	—	.04	.01	.03	—	.001
BS vs YS × I	—	.07	.01	.002	—	—	.001
F	—	—	—	—	—	—	.001
C vs S × F	—	—	.01	.003	—	—	.003
BS vs YS × F	—	—	—	—	—	—	.001
I × F	—	.10	—	—	—	—	.001
C vs S × I × F	.05	.04	—	—	—	—	.001
BS vs YS × I × F	—	.007	—	.08	.09	.07	.001
SE	.8	1.4	2.9	2.3	15	17	.10

[a] Five pigs/treatment.

[b] C = corn, BS = bronze sorghum, YS = yellow sorghum, S = sorghums (BS+YS), I = optimal irrigation, MI = minimal irrigation, F = N fertilized, and NF = no N fertilizer.

[c] DMD = DM digestibility, ND = N digestibility, BV = biological value, NR = N retention, DE = digestible energy, ME = metabolizable energy, and UE = utilizable energy (ME × grain yield).

[d] Dashes indicate P>.10.

Table 6. Cost of Grain Production

	Corn[a]				Bronze sorghum				Yellow sorghum			
	I		MI		I		MI		I		MI	
Item	F	NF	F	NF	F	NF	F	NF	F	NF	F	NF
Year 1, variable costs/acre, $												
Labor	31.1	31.1	15.5	15.5	20.7	20.7	5.2	5.2	20.7	20.7	5.2	5.2
Seed	21.2	21.2	14.9	14.9	5.2	5.2	2.3	2.3	5.2	5.2	2.3	2.3
Irrigation	128.7	128.7	54.4	54.4	69.5	69.5	24.8	24.8	69.5	69.5	24.8	24.8
Fertilizer	11.0	0	11.0	0	11.0	0	11.0	0	11.0	0	11.0	0
Herbicide, planting, and cultivation[b]	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0
Harvesting and hauling	22.7	22.2	17.7	17.1	23.8	23.3	19.1	18.3	25.3	24.1	17.9	17.7
Interest on 1/2 of variable costs	15.1	14.4	9.0	8.3	10.0	9.4	6.0	5.3	10.1	9.4	5.9	5.2
Fixed costs/acre, $[c]	72.1	72.1	72.1	72.1	72.1	72.1	72.1	72.1	72.1	72.1	72.1	72.1
Total costs/acre, $	338.9	326.7	231.6	219.3	249.3	237.2	177.5	165.0	250.9	238.0	176.2	164.3
Year 2, variable costs/acre, $												
Labor	20.7	20.7	15.5	15.5	20.7	20.7	5.2	5.2	20.7	20.7	5.2	5.2
Seed	21.2	21.2	14.9	14.9	5.2	5.2	2.3	2.3	5.2	5.2	2.3	2.3
Irrigation	89.1	89.1	69.1	69.1	89.1	89.1	29.6	29.6	89.1	89.1	29.6	29.6
Fertilizer	11.0	0	11.0	0	11.0	0	11.0	0	11.0	0	11.0	0
Herbicide, planting, and cultivation[b]	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0
Harvesting and hauling	25.4	24.9	24.2	23.2	25.4	21.5	23.2	22.1	25.5	24.7	21.2	21.6
Interest on 1/2 of variable costs	12.3	11.6	10.3	9.6	11.3	10.4	6.5	5.8	11.3	10.6	6.4	5.7
Fixed costs/acre, $[c]	72.1	72.1	72.1	72.1	72.1	72.1	72.1	72.1	72.1	72.1	72.1	72.1
Total costs/acre, $	288.8	276.6	254.1	241.4	271.8	256.0	186.9	174.1	271.9	259.4	184.8	173.5

[a] I = optimal irrigation, MI = minimal irrigation, F = N fertilized, and NF = no N fertilizer.

[b] Herbicide costs = $15/acre, seedbed preparation and planting cost=$17/acre, and cultivation cost=$5/acre.

[c] Real estate taxes @ 1%=$6.80/acre, interest on land @ 12%=$40.50/acre, depreciation of irrigation equipment=$15.50/acre, and interest on irrigation equipment @ 2%=$9.30/acre.

Table 7. Effect of Irrigation and Nitrogen Fertilizer on Cost of Utilizable Nutrient per Acre in Pigs

	Year 1				Year 2			
Item[a]	CUN, $/lb[b]	CUE, $/Gcal[b]	UNW, lb/in[b]	UEW, Gcal/in[b]	CUN, $/lb[b]	CUE, $/Gcal[b]	UNW, lb/in[b]	UEW, Gcal/in[b]
C-I-F	1.32	36.79	1.51	.257	.96	25.53	1.60	.289
C-I-NF	1.46	37.82	1.33	.243	1.05	25.30	1.40	.280
C-MI-F	1.93	45.10	1.20	.249	1.02	24.44	1.47	.297
C-MI-NF	2.29	50.60	.97	.210	1.12	25.29	1.28	.272
BS-I-F	.94	24.98	2.31	.421	.85	23.41	1.70	.297
BS-I-NF	.93	24.63	2.23	.406	1.34	30.64	1.02	.214
BS-MI-F	1.18	28.64	2.18	.421	.83	19.10	1.73	.361
BS-MI-NF	1.10	29.72	2.15	.376	.76	19.33	1.77	.332
YS-I-F	.87	22.04	2.51	.480	1.21	23.86	1.18	.292
YS-I-NF	.89	23.07	2.32	.435	1.03	23.55	1.34	.282
YS-MI-F	1.41	34.10	1.77	.351	.86	22.49	1.66	.303
YS-MI-NF	1.35	33.14	1.73	.337	.73	20.71	1.83	.310
Contrasts and Probabilities								
C vs S	.001	.001	.001	.001	.01	.001	.09	.001
BS vs YS	—[c]	.002	—	—	—	.01	—	.08
I	.001	.001	.001	.001	.001	.001	.001	.001
C vs S × I	.001	.001	—	.001	.001	.001	.001	.001
BS vs YS × I	.02	.001	.002	.001	—	.001	—	.001
F	—	.001	.07	.001	—	.001	.02	.001
C vs S × F	.01	.001	—	—	—	.002	—	.005
BS vs YS × F	—	—	—	—	.001	.001	.001	.001
I × F	—	.02	—	—	.01	.001	.02	.001
C vs S × I × F	—	.001	—	.04	.05	.001	—	.001
BS vs YS × I × F	—	.008	—	.001	.001	.001	.006	.001
SE	.09	.42	.72	.004	.05	.22	.51	.003

[a] C = corn, BS = bronze sorghum, YS = yellow sorghum, S = sorghums (BS+YS), I = optimal irrigation, MI = minimal irrigation, F = N fertilized, and NF = no N fertilizer.

[b] CUN = cost per lb of utilizable nitrogen, CUE = cost per Gcal of utilizable energy, UNW = utilizable nitrogen per in of available water, and UEW = utilizable energy per in of available water.

[c] Dashes indicate P>.10.

IN VITRO DIGESTIBILITY OF SORGHUM PARENT LINES PREDICTS NUTRITIONAL VALUE OF THEIR HYBRID OFFSPRING IN CANNULATED FINISHING PIGS

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Summary

Nutritional value of eight sorghum hybrids, resulting from matings of four male lines with two male-sterile lines, was determined. The male lines were two sorghums with consistently high in vitro digestibility (High-digestibility 1 and High-digestibility 2) and two sorghums with consistently low in vitro digestibility (Low-digestibility 1 and Low-digestibility 2). The male-sterile lines were Kansas 52 and Redlan, two lines commonly used for genetic testing by sorghum breeders. The hybrids were fed to eight barrows fitted with ileal T-cannulas and also evaluated for starch digestibility in ruminal fluid. Corn was used as a control. Corn had greater ileal and total tract digestibilities of DM, GE, N, and starch than the hybrids, but was similar to the sorghums for starch digestibility in ruminal fluid. Ileal digestibilities were not different for the male-sterile parent lines, but hybrids of Kansas 52 had greater DM, GE, and N digestibilities over the total tract than hybrids of the Redlan parent line. Among the male parent lines, hybrids from the two lines with high in vitro digestibility had greater total tract digestibilities of DM, GE, and N than lines with low in vitro digestibilities. In conclusion, selection based on our laboratory procedure was an effective predictor of total tract nutrient digestibility of sorghum in pigs. Also, differences among parent lines for nutrient digestibility were still evident in their hybrid offspring.

(Key Words: Finishing, Sorghum, Digestibility, In Vitro.)

Introduction

Sorghum grain often is considered variable in nutrient content and quality, with a relative feeding value of 93 to 97% that of corn. However, there are reports of sorghums with nutritional value equal to that of corn, indicating that environment, genotype, processing, and(or) other factors can combine to produce sorghums with excellent feeding value. Costs of elaborate processing techniques and lack of an effective means to control the environment make genetic improvement a preferred goal. To accomplish this, plant breeders must have simple and appropriate tests for likely nutritional value to avoid discarding valuable germplasm. Animal feeding experiments require large amounts of test material and are time consuming, labor intensive, and costly, all of which limit their use as screening tools for plant breeding programs. In the 1991 KSU Swine Day Report, we suggested that in vitro protein digestibility (i.e., a laboratory assay) could be used to select sorghum parent lines with greater nutritional value for broiler chicks and finishing pigs. The objective of the experiment reported herein was to determine the nutritional value of sorghum hybrids, resulting from parent lines selected for different in vitro protein digestibility, in cannulated finishing pigs and ruminal fluid.

Procedures

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Sorghum parent lines were selected from 100 S_2 families of the sorghum population KP7B. Two lines having consistently low (Low-digestibility 1 and 2) and two having consistently high (High digestibility 1 and 2) in vitro pepsin digestibility were selected and grown for two generations to increase quantities of seed. These parent lines were evaluated for nutritional value in broiler chicks and finishing pigs, and the results from those experiments were reported in the 1991 KSU Swine Day Report (page 27). The parent lines with greater in vitro digestibility were indeed of greater nutritional value for chicks and pigs. However, sorghums are marketed as hybrids, not parent lines. Thus, we still questioned whether the differences in the parent lines would be passed to their hybrid offspring.

To evaluate the differences in nutritional value of the parent lines when used to create hybrid offspring, the four sorghum lines were mated with two male-sterile lines (Kansas 52 and Redlan). The resulting eight hybrids were evaluated in pigs (ileal digestibility experiment) and an in vitro starch degradation assay using ruminal fluid. Corn was included as a control. Eight barrows, fitted with ileal T-cannulas, were used in an incomplete Latin square design with pig and period as the blocking criteria. Initial body wt of the barrows was 212 lb. The barrows were housed in metabolism crates (2 ft × 5 ft) for the experiment.

The basal diet was corn-soybean meal-based and formulated to 15% CP, .65% Ca, and .55% P (Table 1). The sorghums were used to replace the corn on a wt/wt basis, with all grains ground through a hammermill with a 1/8" screen. Chromic oxide was added to the diets as an indigestible marker. Water was provided ad libitum, and feed was provided using the equation: daily feed=.05 × body $wt^{.9}$. Feed was offered as a wetted mash in two equal portions at 7 a.m. and 7 p.m. each day. Collection periods consisted of a 4-d adjustment to diet followed by 36 h of total feces collection and 2 d (12 h/d) of ileal digesta collection. Feces and ileal digesta were homogenized, dried, and ground prior to analyses for DM, N, GE, and starch concentrations.

Table 1. Composition of the Basal Diet[a]

Item	Amount, %
Grain source	77.58
Soybean meal (48% CP)	19.46
Dicalcium phosphate	1.03
Limestone	1.03
Salt	.25
Vitamins and minerals[b]	.40
Chromic oxide[c]	.25
Total	100.00

[a] Formulated with corn to 15% CP, .65% Ca, and .55% P; other grain sources replaced corn on a wt:wt basis.

[b] KSU vitamin and mineral premixes.

[c] Chromic oxide was added as an indigestible marker.

For determination of digestibility in ruminal fluid, cleaned whole grain was ground in a laboratory mill equipped with a 1 mm screen. Ruminal fluid was collected from a fistulated steer, strained through cheesecloth, and transported to the lab. Inoculum was made by mixing McDougall's buffer with the ruminal fluid, and 15 mL of inoculum was added to test tubes containing .5 g of cereal grain. The tubes were filled with CO_2 and incubated at 102°F, and the fermentation was stopped in two tubes per treatment at 4, 8, 12, 16, and 24 h by adding ice-cold acetate buffer. Rate of starch degradation was calculated by regressing the natural log of percentage starch remaining vs duration of incubation.

Data were analyzed with the contrasts: 1) corn vs the sorghums; 2) Kansas 52 vs Redlan; 3) Low-digestibility 1 and Low-digestibility 2 vs High-digestibility 1 and High-digestibility 2; 4) Low-digestibility 1 vs Low-digestibility 2; 5) High-digestibility

1 vs High-digestibility 2; 6) Low-digestibility 1 and Low-digestibility 2 vs High-digestibility 1 and High-digestibility 2 × Kansas 52 vs Redlan; 7) Low-digestibility 1 vs Low-digestibility 2 × Kansas 52 vs Redlan; and 8) High-digestibility 1 vs High-digestibility 2 × Kansas 52 vs Redlan. In the in vitro starch degradation assay, the model included the main effects of grain source and the interaction of grain source × duration of incubation.

Results and Discussion

The hybrids varied in pericarp color (i.e., red, yellow, brown, and mixed), and hybrids with Low-digestibility 1 as a parent had moderate (.56 and 1.53 mg catechin/100 mg DM) levels of tannins as did the Low-digestibility 2 × Redlan hybrid (.97 mg catechin/100 mg DM). Tannins are associated with the presence of a pigmented testa. The presence or absence of the pigmented testa is controlled by two complementary genes, with the testa present when both genes are dominant. Thus, expression of these genes accounts for not only the detectable levels of tannin, but also the brown and mixed pericarp colors for the Low-digestibility 1 × Kansas 52, Low-digestibility 1 × Redlan, and Low-digestibility 2 × Redlan hybrids.

Nutrient digestibilities at the terminal ileum ($P<.001$) and for the total tract ($P<.07$) were greater for corn than the sorghum hybrids, but disappearance of starch in the large intestine was greater for the sorghum hybrids ($P<.001$). Starch disappearing in the large intestine would be used largely for microbial activity and is of less benefit to the host animal. Thus, total tract digestibility of starch would overestimate the nutritional value of the sorghum hybrids relative to corn.

For the sorghums, digestibilities of nutrients at the terminal ileum were similar for hybrids from Kansas 52 and Redlan, but total tract digestibilities of DM, GE, and N were greater ($P<.05$) for hybrids from Kansas 52. Selected line × male-sterile interactions for total tract DM digestibility were detected, probably because of the expression of the tannin genes in the Low-digestibility 2 × Redlan mating.

Digestibility of nutrients at the terminal ileum were similar ($P>.13$) for hybrids from High-digestibility 1 and 2 and Low-digestibility 1 and 2 parent lines. However, total tract digestibilities of DM, GE, and N were greater ($P<.01$) for hybrids from the High-digestibility vs Low-digestibility parent lines. This was undoubtedly because of tannins in the hybrids from Low-digestibility parent lines.

Digestibilities of nutrients at the terminal ileum were greater ($P<.01$) for hybrids from High-digestibility 2 than High-digestibility 1, whereas total tract digestibilities of nutrients were similar ($P>.10$). As previously discussed, nutrients absorbed in the small intestine are of greater value to the pig than those digested and absorbed in the large intestine. Thus, the hybrids of High-digestibility 2 would be of greater nutritional value to the animal. Starch degradation in ruminal fluid did not differ for the sorghums.

In conclusion, results of this experiment support our earlier findings that in vitro pepsin digestibility can be used to rank sorghum grains for overall nutrient utilization by pigs. Moreover, selected parent lines passed those differences to their hybrid progeny. However, the male-sterile parents had greater effects on nutritional value of the offspring than the male parents. Thus, if male-steriles with high protein digestibility could be found or developed, it would simplify breeding for improved nutritional value in sorghum grain.

Table 2. Composition of Corn and Sorghum Hybrids[ab]

		Kansas 52				Redlan			
Item	Corn	LD1	LD2	HD1	HD2	LD1	LD2	HD1	HD2
Physical traits									
Pericarp color	—	mixed	yellow	red	yellow	brown	brown	red	red
Endosperm									
Color	—	hetero	white	white	white	white	white	white	white
Texture	—	3	2	3	2	4	2	3	4
Type	normal	normal	normal	normal	normal	normal	normal	normal	normal
Chemical analyses									
CP, %	8.4	12.2	13.7	13.2	12.6	11.5	13.0	12.5	12.2
Fat, %	5.6	4.2	3.9	4.3	4.0	3.4	3.3	4.1	4.5
Ash, %	1.1	2.0	1.9	1.9	1.9	1.9	1.7	1.9	2.1
Starch, %	73.9	72.9	74.3	74.1	74.0	75.4	73.9	72.9	74.5
GE, Mcal/lb	2.13	2.06	2.11	2.10	2.10	2.09	2.10	2.11	2.09
Moisture, %	12.7	13.1	13.2	13.7	13.3	13.7	12.9	13.3	13.6
Tannin[c]	ND	.56	ND	ND	ND	1.53	.97	ND	ND
Pepsin digestibility, %	74.4	50.0	61.4	54.7	59.1	42.2	43.2	60.9	59.7
Amino acids, %									
Lysine	.30	.28	.28	.29	.28	.29	.29	.30	.27
Methionine	.20	.25	.23	.25	.22	.26	.23	.23	.20
Threonine	.33	.41	.40	.44	.42	.43	.42	.42	.36
Tryptophan	.04	.07	.09	.10	.04	.09	.08	.10	.04

[a] Dry matter basis.

[b] LD1=Low-digestibility 1; LD2=Low-digestibility 2; HD1=High-digestibility 1; and HD2=High-digestibility 2.

[c] Milligrams of catechin/100 mg grain DM.

Table 3. Apparent Nutrient Digestibility in Pigs and Starch Degradation in Ruminal Fluid of Corn and Sorghum Hybrids[a]

		Kansas 52[b]				Redlan[b]					Contrasts[cd]							
Item	Corn	LD1	LD2	HD1	HD2	LD1	LD2	HD1	HD2	SE	1	2	3	4	5	6	7	8
Dry matter, %																		
Small intestine	78.08	70.41	68.05	67.80	69.23	67.78	68.64	69.43	70.83	.58	.001	—	—	—	.007	—	—	—
Total tract	87.67	84.09	86.70	86.06	86.53	83.14	82.77	86.48	85.79	.26	.005	.04	.01	—	—	.08	.09	—
Difference[e]	9.59	13.68	18.65	18.26	17.30	15.36	14.13	17.05	14.96	.59	.001	—	—	—	.01	—	—	—
Gross energy, %																		
Small intestine	79.66	71.08	68.26	67.90	69.72	68.75	69.49	69.95	71.17	.60	.001	—	—	—	.005	—	—	—
Total tract	87.34	82.58	85.29	84.39	85.32	81.61	80.95	84.91	84.08	.31	.001	.05	.01	—	—	—	—	—
Difference	7.68	11.50	17.03	16.49	15.60	12.86	11.46	14.96	12.91	.60	.001	—	—	—	.02	—	—	—
Nitrogen, %																		
Small intestine	80.60	70.42	70.35	69.75	70.64	69.16	68.66	72.75	72.84	.57	.001	—	—	—	.007	—	—	—
Total tract	85.03	75.16	79.14	79.25	79.15	73.82	72.52	78.06	77.53	.52	.001	.03	.01	—	—	—	—	—
Difference	4.43	4.74	8.79	9.50	8.51	4.66	3.86	5.31	4.69	.75	—	.07	—	—	—	—	—	—
Starch, %																		
Small intestine	97.57	91.15	87.77	87.73	90.51	89.53	89.50	90.16	90.76	.45	.001	—	—	—	.009	—	—	—
Total tract	99.71	98.97	99.22	99.39	99.38	99.26	98.55	99.30	99.24	.09	.07	—	—	—	—	—	—	—
Difference	2.14	7.82	11.45	11.66	8.87	9.73	9.05	9.14	8.48	.47	.001	—	—	—	.01	—	—	—
In vitro degradation																		
% starch/h[f]	3.27	3.13	3.16	3.04	3.15	2.97	3.01	3.17	3.25	.04	—	—	—	—	—	—	—	—

[a] Values for digestibilities in pigs are means of five or six pigs with chromic oxide used as an indigestible marker. Values for starch degradation in ruminal fluid are for 10 test tubes each.

[b] LD1=Low-digestibility 1; LD2=Low-digestibility 2; HD1=High-digestibility 1; and HD2=High-digestibility 2.

[c] Contrasts: 1) Corn vs Sorghums; 2) Kansas 52 vs Redlan; 3) LD1 and LD2 vs HD1 and HD2; 4) LD1 vs LD2; 5) HD1 vs HD2; 6) LD1 and LD2 vs HD1 and HD2 × Kansas 52 vs Redlan; 7) LD1 vs LD2 × Kansas 52 vs Redlan; and 8) HD1 vs HD2 × Kansas 52 vs Redlan.

[d] Dashes indicate $P>.10$.

[e] Difference was calculated by subtracting small intestine digestibility from total tract digestibility.

[f] Degradation rate was calculated by regressing the natural log of percentage starch remaining on duration of incubation.

LOW PROTEIN CORN DOES NOT INFLUENCE FINISHING PIG PERFORMANCE

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Summary

A total of 150 pigs was used to evaluate the effects of corn with different crude protein content on growth performance of finishing pigs. Our objective was to determine if low protein corn might result in poorer pig performance compared with pigs fed diets containing corn with a normal protein content. Control pigs were fed a diet containing corn with a crude protein content of 8.5% and formulated with soybean meal to 14.6% crude protein (.70% lysine). Pigs were also fed a diet with low crude protein corn (7.5%), which was substituted on an equal weight basis for normal corn resulting in a diet containing 13.5% crude protein. Pigs were fed a third diet using low protein corn, but formulated to 14.6% crude protein by increasing the level of soybean meal in the diet. No differences were observed in average daily gain (ADG) and average daily feed intake (ADFI) of the pigs fed any of the experimental diets; however, pigs fed the low protein corn diet without added soybean meal were the most efficient. These results indicate that low crude protein corn (7.5%) will not adversely affect finishing pig growth performance. In addition, supplemental protein apparently is not necessary when using low protein corn in diets for finishing pigs.

(Key Words: Corn, G-F, Performance.)

Introduction

Because of the extensive moisture in the Midwest last year, the corn and other grain crops produced lower crude protein values than typically observed. The low crude protein content caused speculation that pig performance might be adversely affected if diets were not adjusted for the decreased protein content. However, research conducted at other universities has suggested that the essential amino acid profile remains relatively constant when the protein content of corn changes. Therefore, the objectives of this experiment were to determine the effects of feeding low crude protein corn on growth performance of pigs fed from 135 to 240 lb and to determine if additional protein fortification is necessary.

Procedures

Low crude protein corn was purchased from south-central Nebraska, and the control corn was from a producer in northeast Kansas. Samples of the corn were collected and analyzed for crude protein content, and diets were formulated from analyzed values. The control diet was formulated to 14.6% crude protein (.70% lysine) with 8.5% protein corn (Table 1). Additional diets were formulated by substituting the low crude protein corn on an equal weight basis for the normal corn (13.5% CP). A third diet was formulated with the low crude protein corn and additional soybean meal to reach a total of 14.6% crude protein.

One hundred and fifty finishing pigs (initially 135 lb) were randomly assigned by sex, ancestry, and initial weight to one of the three dietary treatments in a randomized complete block design. Pigs were housed in a modified open-front building and allowed ad libitum access to feed and water. There were ten pigs per pen and five replications per treatment. The study was concluded when the final weight of pigs reached 240 lb. At the conclusion of the study, all pigs were scanned with a Scan-o-probe at the last rib to determine fat depth.

Results and Discussion

Average daily gain and ADFI were unaffected (P>.30) by dietary treatment (Table 2). However, pigs fed the diet containing low protein corn without added soybean meal had improved feed efficiency compared with pigs fed the other dietary treatments. Last rib fat depth was not affected by dietary treatment. These results indicate that small variations (8.5 to 7.5%) in the crude protein content of corn do not adversely affect pig performance. Furthermore, adding soybean meal to the diet to account for the decreased protein content of the corn had no benefit on pig performance and, thus, would not be economically justified. Research evaluating the relationship between the protein content and amino acid profile of corn suggests that when the protein content increases or decreases, this is a result of changes in nonessential amino acids rather than essential amino acids such as lysine. Our findings would support this concept. In conclusion, feeding finishing pigs diets containing corn with either 8.5 or 7.5% crude protein had no effect on performance.

Table 1. Diet Composition

Ingredient, %	Control	Low Crude Protein Corn	Low Crude Protein + Soybean Meal
Corn (normal)	80.91	--	--
Corn, low CP	--	80.91	78.33
SBM 48%	16.43	16.43	19.06
Monocalcium phosphate	1.03	1.03	.99
Limestone	.93	.93	.92
Vitamin premix	.15	.15	.15
Trace mineral premix	.10	.10	.10
Salt	.35	.35	.35
Antibiotic[a]	.10	.10	.10
Total	100.00	100.00	100.00
Calculated Analysis			
CP	14.6	13.5	14.6
Lysine	.70	.70	.77
C	.65	.65	.65
P	.55	.55	.55

[a] Provided 50 g/ton of chlortetracycline.

Table 2. Effects of Low Crude Protein Corn on Pig Performance[a]

Item	Control	Low Crude Protein Corn	Low Crude Protein Corn + SBM
ADG, lb	1.94	1.95	1.97
ADFI, lb	7.39	7.19	7.51
F/G	3.81[b]	3.68[c]	3.79[b]
Last rib backfat, in	.86	.84	.83

[a] A total of 150 pigs with 10 pigs per pen and 5 replications per treatment. Average initial wt = 137 lb and average final wt = 240 lb.

[bc] Means on the same row with different superscripts differ (P<.05).

SORGHUM GENOTYPE AND PARTICLE SIZE AFFECT GROWTH PERFORMANCE, NUTRIENT DIGESTIBILITY, AND STOMACH MORPHOLOGY IN FINISHING PIGS

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Summary

Seventy pigs (average initial body wt of 119 lb) were used to determine the effects of sorghum genotype on milling characteristics, growth performance, nutrient digestibility, and stomach morphology in finishing pigs. The pigs were fed a corn-soybean meal-based control diet, with the corn (Pioneer 3377) milled to a mean particle size of 600 µm. Hard-endosperm sorghum (Pioneer 8585) and soft-endosperm sorghum (Pioneer 894) were milled to mean particle sizes of 800, 600, and 400 µm and substituted for the corn in the control diet on a wt/wt basis, so that the overall treatment arrangement was a 2 × 3 factorial plus control. The sorghums required less energy to grind, had greater production rates, and produced less noise during milling than the corn. Pigs fed the diets with hard and soft endosperm sorghum had average daily gain, average daily feed intake, and feed/gain similar to those fed corn. Pigs fed hard sorghum grew faster, but pigs fed soft sorghum were more efficient. As particle size was decreased, energy required for grinding increased and production rate slowed. Efficiency of gain and nutrient digestibility were maximized and excretion of nutrients as feces was minimized at 400 µm for both hard- and soft-endosperm sorghum. Considering the positive effects of fine grinding on efficiency of gain and nutrient digestibility, but the negative effects on energy required for milling, production rate and stomach morphology, an acceptable compromise for particle size of soft and hard sorghum in pelleted diets for finishing pigs will still likely be less than 600 µm.

(Key Words: Sorghum, Process, Noise, Stomach, Digestibility, Finishing.)

Introduction

Grain sorghums have agronomic characteristics, such as resistance to heat stress and drought, that contribute to their cultivation in preference to corn in several regions of the world. However, sorghum grain is usually considered to have about 5% less feeding value than corn.

In the past few years, several experiments have been conducted to identify processing procedures that give consistent improvements in performance of pigs fed sorghum. Researchers at Arkansas reported that micronizing brown-seeded sorghum improved feed/gain (F/G) in finishing pigs, and data from KSU indicated improved F/G in nursery and finishing pigs fed diets with extruded sorghum compared to ground sorghum. However, cold grinding is by far the most common method of preparing cereals for use in livestock diets, and few data are available to determine the particle size of sorghum grain that would make it most competitive with corn. We used two sorghum genotypes that differed in endosperm hardness to determine if soft sorghum grain might require less processing

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that hard sorghum grain to achieve maximum nutritive value.

Materials and Methods

Corn (Pioneer 3377), hard-endosperm sorghum (Pioneer 8585), and soft-endosperm sorghum (Pioneer 894) were grown at Manhattan, KS and harvested in the fall of 1992. The grains were analyzed for crude protein, fat, ash, gross energy, and moisture using standard analytical procedures. Also, tannin content of the sorghums was determined and expressed as catechin equivalents. Treatments included a corn-based control diet, with the corn milled to a mean particle size of 600 µm. This particle size was suggested as the optimum for corn in meal or pelleted finishing diets by Wondra et al. in the 1992 KSU Swine Day Report (page 122). The hard- and soft-endosperm sorghums were milled to mean particle sizes of 800, 600, and 400 µm, so that the overall treatment arrangement was a 2 × 3 factorial plus control. The corn, hard-endosperm sorghum, and soft-endosperm sorghum had 12.9, 13.0, and 13.0% moisture, respectively, when milled, and the particle size determinations were made using sieves with Tyler numbers 4, 6, 8, 10, 14, 20, 28, 35, 48, 65, 100, 150, 200, 270, and a pan. A Ro-Tap® shaker was used to sift the 100 g samples for 10 minutes. The cereal grains were milled using a three-high roller mill (1:1, 1.5:1, and 1.5:1 differential drives; 6:6, 10:12, and 16:18 corrugations per in for the fast:slow rolls; and 1 in of spiral per ft of roller; Model K, Roskamp Manufacturing). An audio dosimeter was used to measure the noise level during grinding of each grain. All diets were formulated to .7% lysine, .65% Ca, and .55% P (Table 1) and were pelleted in a 30 horsepower pellet mill. The die of the pelleter was 1.5 in thick with 3/16 in diameter holes, and steam was used before pelleting to condition the diets to 149° F. Samples of the finished diets were analyzed for pellet durability. Electrical energy consumption during grinding and pelleting was measured using an amperage/voltage strip chart recorder. The average voltage and amperage during processing were calculated and used to determine electrical consumption for each batch of feed.

The experimental diets were fed to a total of 70 crossbred barrows (119 lb average initial body wt). The pigs were housed in an enclosed, environmentally controlled building with slatted flooring. There were two pigs per pen and five pens per treatment. Each pen (5 ft × 5 ft) had a nipple waterer and a single-hole self-feeder so water and feed could be consumed on an ad libitum basis. On d 50 of the experiment, chromic oxide was added to the diets as an indigestible marker. After a 5-d adjustment period, samples of feces were collected from each pig and pooled within pen. The feed and fecal samples were dried and analyzed for dry matter (DM), nitrogen (N), gross energy (GE), and chromium concentrations to allow calculation of apparent DM, N, and GE digestibilities. The pigs were fed to an average ending weight of 250 lb and slaughtered for collection of hot carcass weights, last rib fat thicknesses, and stomach tissues. Stomach tissues were evaluated for severity of keratinization and esophagogastric ulcers using scoring systems where keratinization was 1 = normal, 2 = mild parakeratosis, 3 = moderate parakeratosis, and 4 = severe parakeratosis and ulceration was 1 = normal, 2 = erosion, 3 = ulcer, and 4 = severe ulcer.

Pig performance, nutrient utilization, and carcass data were analyzed as a randomized complete block design, with a 2 × 3 factorial plus control arrangement of treatments. Pen served as the experimental unit. Final body wt was used as a covariate for analyses of backfat thickness and dressing percentage. Treatment comparisons were made using the contrasts: 1) corn vs sorghum treatments; 2) hard sorghum vs soft sorghum; 3) linear effect of particle size; 4) quadratic effect of particle size; 5) hard sorghum vs soft sorghum × linear effect of particle size; and 6) hard sorghum vs soft sorghum × quadratic effect of particle size. Because the stomach scores were categorical data, they were tested for significant main effects of grain type and particle size using a row mean scores differ test for categorical data.

Results and Discussion

The soft- and hard-endosperm sorghums were genotypes with normal (nonwaxy) white starch, red pericarp, and low tannin (Table 2). Crude protein concentrations were 7.7 for corn, 9.5 for hard sorghum, and 10.5 for soft sorghum. Percentage fat, ash, and gross energy were similar for the three grains.

As mean particle size was decreased, energy required for grinding increased and production rate was slowed (Table 3). More energy was required to grind corn to 600 µm than to grind the sorghums to 600 µm. Also, hard-endosperm sorghum required more energy for grinding to 800 and 600 µm than soft sorghum, but similar energy inputs were required to grind the sorghums to 400 µm. Sorghum genotype had little effect on pelleting efficiency or pellet durability.

Noise pollution was greater during milling of the corn than of the sorghums, and hard sorghum produced more noise than soft sorghum. When compared to OSHA standards for tolerable noise levels, these data suggest that hearing protection would be required when corn is ground, but not when sorghums are ground. Further research in this area is needed to evaluate the potential for hearing damage during cold grinding of different grains.

For ADG, ADFI, and F/G, no differences were observed ($P>.10$) among the corn control and sorghums (Table 4). Pigs fed the hard-endosperm sorghum gained 4% faster than pigs fed soft-endosperm sorghum ($P<.05$). However, pigs fed soft-endosperm sorghum consumed 7% less feed ($P<.01$) and were 3% more efficient ($P<.01$) than pigs fed hard-endosperm sorghum. Linear decreases in ADFI and F/G were noted as mean particle size of the diets was reduced from 800 to 400 µm ($P<.01$). These results agree with previous reports of improved efficiency of gain as particle size is reduced below the typical sizes of 800 to 1,000 µm.

Several researchers have reported little or no difference in carcass characteristics as particle size of diets is decreased. In our experiment, reduction of particle size did not affect dressing percentage or last rib backfat thickness ($P>.10$). However, sorghum genotype did affect carcass measurements, with pigs fed hard endosperm sorghum having 8% greater last rib backfat thickness ($P<.05$). This increase in last rib backfat thickness in pigs fed the hard-endosperm sorghum probably resulted from their greater feed intakes.

Apparent digestibilities of DM and GE were greater ($P<.01$) for the sorghums than for the corn (Table 5). This was especially true when the sorghum was ground to 400 µm. No difference in digestibility of N was observed among the corn-based control and the sorghum treatments ($P>.10$). These responses were unexpected, because corn routinely has greater nutrient digestibility than sorghum. Similar discrepancies with the "norm" (i.e., corn>sorghum) have been reported by other researchers from time to time and suggest that genotype, growing conditions, processing methods, and(or) other unknown factors can contribute to make sorghum similar to corn in nutritional value. When the two sorghum genotypes were compared, soft-endosperm sorghum had greater DM, N, and GE digestibility than hard-endosperm sorghum ($P<.01$). However, there were sorghum genotype × particle size interactions ($P<.05$) for digestibilities of DM, N, and GE. Nutrient digestibility increased in a linear manner as particle size of soft-endosperm sorghum was reduced from 800 to 400 µm. However, for the hard-endosperm sorghum, the apparent digestibilities decreased as particle size was reduced from 800 to 600 µm and then increased as particle size was reduced from 600 to 400 µm. This quadratic response for the hard sorghum is difficult to explain and likely can be attributed to random error in the titration curve.

In the last few years, the contribution of intensive animal production to environmental pollution has become a matter of concern. Some countries of the European community have already introduced strong regulations to reduce the amounts of DM, N, and mineral excretions. In our experiment, reducing particle size from 800 to 400 µm reduced fecal excretions of DM and N by 14 and 33%, respectively, for pigs fed hard-endosperm sorghum and by 59 and 60%, respectively, for pigs fed soft-endosperm sorghum. These results suggest that increased production costs, because of environmental regulations, can be reduced by proper processing of swine diets.

It is well documented that the incidence of stomach ulcers in swine can be increased by pelleting and use of finely ground grain. Some have suggested that reduction of particle size results in greater acid secretion and pepsin activity in the stomach. This mixture of stomach contents, acid, and enzymes contacts the relatively unprotected esophageal region of the stomach leading to development of ulcers. In our experiment, scores for degree of keratinization and gastric lesions were not affected by grain source (P>.10). Reduction of particle size increased the incidence and severity of gastric lesions for both hard- and soft-endosperm sorghums (P<.05), but even at 400 µm, the scores for the sorghums were less than those for corn ground to 600 µm.

In conclusion, pigs fed the diets with hard- or soft-endosperm sorghum had similar ADG, ADFI, and F/G to those fed corn. Also, the sorghums required less energy to grind, had greater production rates, and produced less noise during milling than the corn. Efficiency of gain and nutrient digestibility was maximized at 400 µm for both hard- and soft-endosperm sorghums. Considering the positive effects of fine-grinding on efficiency of gain and nutrient digestibility, but the negative effects on energy required for milling, production rate, and stomach morphology, an acceptable compromise for particle size of soft and hard sorghums in pelleted diets for finishing pigs will still likely be less than 600 µm.

Table 1. Diet Composition[a]

Item	Control Diet, %	Sorghum Diets, %
Corn	82.47	—
Sorghum	—	82.45
Soybean meal (48% CP)	14.75	14.75
Monocalcium phosphate	1.07	1.07
Limestone	1.02	1.02
L-lysine HCl	.04	.06
Salt	.30	.30
Vitamin premix[b]	.15	.15
Trace mineral premix[b]	.10	.10
Antibiotic[c]	.10	.10
Total	100	100

[a] The control diet was formulated to 14% CP, .7% lysine, .65% Ca, and .55% P with corn as the cereal grain. Soft- and hard-endosperm sorghums were used to replace corn on a wt/wt basis.
[b] KSU vitamin and mineral premixes.
[c] Provided 100 g/ton chlortetracycline.

Table 2. Chemical Analyses of the Experimental Grains

Item	Corn	Sorghum Endosperm Soft	Hard
Crude protein, %	7.7	10.5	9.5
Fat, %	3.7	3.7	4.0
Ash, %	1.9	1.4	1.3
Gross energy, Mcal/lb	1.79	1.78	1.77
Moisture, %	16.4	15.5	16.9
Tannins, catechin equivalents	ND[a]	ND	ND

[a] ND= none detected (i.e., less than .03 mg/100 mg DM).

Table 3. Effects of Sorghum Genotype on Milling Characteristics

	Corn	Soft Sorghum, µm			Hard Sorghum, µm		
Item	600, µm	800	600	400	800	600	400
Milled grains							
Mean particle size, µm	592	813	605	421	794	607	411
Variation in particle size (s_{gw})	2.12	1.79	1.83	1.77	1.77	1.83	1.77
Grinding							
Energy, kilowatt h/ton	7.0	2.4	4.5	9.1	3.0	6.4	9.1
Production rate, ton/h	.9	2.5	1.3	.8	1.9	1.1	.8
Noise, decibles	95	84	81	85	85	84	86
Pelleting							
Energy, kilowatt h/ton	10.8	9.8	10.1	9.8	10.5	9.3	10.2
Production rate, ton/h	1.3	1.8	1.5	1.2	1.2	1.4	1.2
Fines, %	10.3	9.4	9.5	7.7	10.7	8.9	8.3
Durability, %	89.6	90.6	90.5	92.3	89.3	89.1	91.7

Table 4. Effects of Grain Genotype and Particle Size on Performance, Carcass, and Stomach Lesions in Finishing Pigs[a]

	Corn	Soft Sorghum, µm			Hard Sorghum, µm			
Item	600, µm	800	600	400	800	600	400	CV
ADG,lb[b]	2.18	2.20	2.15	2.18	2.25	2.28	2.29	5.3
ADFI,lb[cd]	7.11	7.48	6.94	6.91	7.78	7.65	7.48	5.0
F/G[cd]	3.26	3.40	3.23	3.17	3.46	3.36	3.27	3.2
Dressing percentage	74.1	74.6	73.5	74.6	74.8	74.9	75.1	1.4
Fat thickness, in[b]	1.47	1.26	1.37	1.34	1.44	1.41	1.44	8.1
Stomach keratinization score	2.8	1.9	2.5	2.5	2.3	2.4	2.5	21.1
Stomach ulcer score[e]	1.6	1.2	1.0	1.4	1.0	1.3	1.6	31.2

[a] A total of 70 pigs with 2 pigs/pen and 5 pens/treatment (avg initial body wt of 119 lb).

[bc] Hard sorghum vs soft sorghum (P<.05; P<.01, respectively).

[d] Linear effect of particle size (P<.01).

[e] Particle size effect (P<.05; Cochran-Mantel-Haenszel statistic, row mean scores differ test).

Table 5. Effects of Grain Genotype and Particle Size on Apparent Digestibility, Intake, and Excretion of Nutrients in Finishing Pigs[a]

	Corn	Soft Sorghum, µm			Hard Sorghum, µm			
Item	600, µm	800	600	400	800	600	400	CV
Apparent digestibilities, %								
DM[cdegh]	86.21	87.07	89.09	90.24	88.38	86.52	89.57	.7
N[deghk]	79.78	75.55	80.99	90.68	79.14	75.47	83.89	1.9
GE[cdeghj]	86.93	87.07	89.23	94.56	88.82	86.87	90.83	.8
DM digested, lb/d[cdg]	5.51	5.86	5.56	5.86	6.19	5.95	6.03	5.0
N digested, lb/d[cdf]	.12	.15	.14	.16	.14	.13	.14	5.3
DM excretion, lb/d[cdeghi]	.88	.87	.68	.36	.81	.92	.70	8.4
N excretion, lb/d[beghk]	.03	.05	.03	.02	.03	.04	.02	10.0

[a] A total of 70 pigs with 2 pigs/pen and 5 pens/treatment (avg initial body wt of 119 lb).

[bc] Corn vs sorghums (P<.10; P<.01, respectively).

[d] Hard sorghum vs soft sorghum (P<.01).

[e] Linear effect of particle size (P<.001).

[fg] Quadratic effect of particle size (P<.10; P<.001, respectively).

[h] Sorghum genotype × linear effect of particle size (P<.001).

[ijk] Sorghum genotype × quadratic effect of particle size (P<.10; P<.05; P<.01, respectively).

EFFECTS OF HAMMERMILLS AND ROLLER MILLS ON GROWTH PERFORMANCE, NUTRIENT DIGESTIBILITY, AND STOMACH MORPHOLOGY IN FINISHING PIGS

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Summary

The effects of particle size and mill type used to grind corn were determined with 128 pigs (122 lb average initial body wt). Treatments were corn ground in a hammermill and a roller mill to 800 and 400 µm. The roller mill was more efficient than the hammermill when grinding the corn, with less energy consumption and greater production rate per horsepower hour. For the 800 µm treatments, greater uniformity of particle size was achieved with the roller mill than the hammermill; however, at the 400 µm treatments, corn ground with the hammermill was slightly more uniform. Pigs fed corn ground to 400 µm had 7% greater efficiency of gain, and had greater digestibilities of dry matter, nitrogen, and energy than pigs fed corn ground to 800 µm. Mill type did not affect growth performance, but pigs fed corn ground in the roller mill had greater digestibilities of dry matter, nitrogen, and energy and excreted 18% less dry matter and 13% less nitrogen as feces than pigs fed corn ground in a hammermill. There were interactions among mill type and particle size, with digestibilities much greater for the diet with corn ground to 800 µm in the roller mill compared to the hammermill, but only small advantages in nutrient digestibility for diets with corn ground to 400 µm in the roller mill. Mill type did not affect rate or efficiency of gain, but pigs fed diets with roller-milled corn had greater digestibilities of nutrients and, thus, lower excretions of nutrients in feces.

(Key Words: Finishing, Process, Roller Mill.)

Introduction

In the last few KSU Swine Day Reports, we have given much attention to the positive effects of reducing mean particle size of cereal grains for nursery pigs (1991, page 56), finishing pigs (1992, page 122), and lactating sows (1992, page 6). From these experiments, we emphasized that reducing mean particle size of cereal grains to ≤ 600 µm resulted in marked improvements in nutrient digestibility and efficiency of growth compared to the relatively coarse sizes of 900 to 1,000 µm. Also, results from other experiments (1992 KSU Swine Day Report, page 126) indicated that particle size uniformity affected nutrient digestibility. This observation has implications for the mill type a producer might elect to purchase. For example, milling with a hammermill to a mean particle size > 800 µm typically yields products with much variation in particle size, but variation decreases with milling to smaller (< 500 µm) particle sizes. In contrast, milling with a roller mill yields grain with a high degree of particle size uniformity regardless of mean particle size. Thus, the experiment reported herein was designed to determine the effects of mill type (hammermill vs roller mill) and particle size (800 vs 400 µm) on grain milling, growth performance, and nutrient utilization.

Procedures

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A total of 128 crossbred finishing pigs (122 lb average initial body wt) was allotted to dietary treatments on the basis of weight, sex, and ancestry. They were housed in a modified open-front building (16 pens of five barrows and three gilts), with 50% solid concrete and 50% concrete slat flooring, and four pens per treatment. Each pen (6 ft × 16 ft) had a two-hole self-feeder and a nipple waterer to allow ad libitum consumption of feed and water.

Corn was ground in a 30 horsepower hammermill (P-240D Pulverator, Jacobson Machine Works) equipped with screens having openings of 3/8 and 1/16 in for the 800 and 400 µm treatments, respectively. Corn also was milled to the same particle sizes using a roller mill (three high; 1:1, 1.5:1, and 1.5:1 differential drives; 6:6, 10:12, and 16:18 corrugations per in for the fast:slow rolls; and 1 in of spiral per ft of roller; Model K, Roskamp Manufacturing). Particle size, particle size uniformity, and surface area of the ground grains and diets were determined with .22 lb samples using a Ro-Tap® shaker and a set of 14 sieves. The motor load of the hammermill and roller mill was held constant at 70% of capacity during milling so that production rate and electrical energy consumption could be measured. The basal diet was the corn-soybean meal-based diet (.65% lysine) given in Table 1. All diets were fed in meal form.

Pigs and feeders were weighed at initiation and conclusion of the growth assay to determine average daily gain (ADG), average daily feed intake (ADFI), and feed/gain (F/G). Six weeks after initiation of the experiment, chromic oxide was added to the diets (.20%) as an indigestible marker. After a 5-d adjustment period, grab samples of feces were collected from two barrows and two gilts in each pen. The fecal samples were dried and pooled within pen on an equal weight basis. Concentrations of chromium, dry matter (DM), nitrogen (N), and gross energy (GE) in the feces and diets were determined to allow calculation of apparent digestibilities of DM, N, and GE using the indirect ratio method. Intakes of digestible DM, N, and GE were calculated by multiplying daily nutrient intakes by their respective apparent digestibilities. The portion of nutrient intake not digested was reported as fecal excretion.

Table 1. Composition of the Basal Diet[a]

Ingredient	%
Corn	82.73
Soybean meal (48% CP)	14.37
Monocalcium phosphate	1.08
Limestone	1.02
Salt	.30
Vitamins and minerals[b]	.40
Antibiotic[c]	.10
Total	100.00

[a] The basal diet was formulated to .65% lysine, .65% Ca, .55% P, and 1.56 Mcal DE/lb.

[b] KSU old vitamin mix (.25%), KSU old mineral mix (.10%), and KSU selenium mix (.05%).

[c] Antibiotic supplied 100 g/ton chlortetracycline.

When a pen in a weight block reached an average body wt of 250 lb, the entire group was removed from the growth assay. One block reached the end weight on d 54, two blocks on d 60, and the last block on d 67 of the experiment. The data were analyzed as a 2 × 2 factorial (main effects of mill type and particle size) with pen as the experimental unit.

Results and Discussion

The actual particle sizes of the ground grains were very close (i.e., within 26 µm) to the targeted particle sizes (Table 2). Reducing particle size decreased variation in particle size and increased surface area of the ground grain from 77.8 to 130.1 cm^2/g. Also, energy required for grinding was increased and production rate was decreased as particle size was reduced. In general, the effects of mill type were less pronounced than those of reducing particle size; nonetheless, mill type did affect particle size uniformity and surface area of the ground corn and diets. Variation in particle size of corn ground in the hammermill was decreased more as particle size was reduced (i.e., s_{gw} from 2.5 to 1.7) compared to corn ground in the roller mill (i.e., s_{gw} from 2.0 to 1.9). Less energy was required to mill corn in the roller mill than in the hammermill, especially at the small particle size. Actual production rates were less for the roller mill than the hammermill because the hammermill had larger capacity; however, standardized production rates, which account for the differences in horsepower capacity of the mills, were still greater for the roller mill. Changes in average particle size, particle size uniformity, and surface area of the complete diets were similar to those observed for the milled corn, which was expected because corn was 83% of the diet.

No interactions occurred among mill type and particle size for growth performance of the finishing pigs (Table 3). Also, the main effect of mill type did not affect growth performance. However, pigs fed the 400 µm treatments had the same ADG and lower ADFI than pigs fed the 800 µm treatments, with the result that F/G was improved 7% (P<.01) by grinding the corn to 400 µm.

Apparent digestibilities of DM (P<.001), N (P<.01), and GE (P<.001) were greater for diets with roller-milled corn than for diets with hammermilled corn and greater for corn ground to 400 vs 800 µm (P<.001). However, the effects of mill type and particle size were not independent. Digestibilities were much lower for the diet with corn ground to 800 µm in the hammermill than for diets with corn ground to 800 µm in the roller mill, resulting in a mill type × particle size interaction (P<.01) for DM and GE digestibilities. However, the advantages in nutrient digestibility for corn ground in the roller mill were less pronounced at 400 µm, where the corn ground in the hammermill had the lowest variation in particle size. This suggested a mill type effect separate from the particle size uniformity effect, albeit less pronounced. Other researchers have described particles of hammermilled corn as more spherical in shape with more uniform edges than particles of roller-milled corn. The spherical shape would reduce susceptibility to attack by enzymes, thus, decreasing digestibility of nutrients in hammermilled corn.

Intake of digestible N was increased by 6% (P<.05) and excretions of DM (P<.001) and N (P<.05) in the feces were decreased 18 and 13%, respectively, when corn was ground in the roller mill vs the hammermill. Although there was a trend for intake of digestible N to increase, fecal excretions of DM and N were still reduced by 18 and 32% when particle size was decreased from 800 to 400 µm (P<.001). Nutrient excretions from animals in regions of intensive animal production can cause problems for the environment; indeed, some countries in Europe already limit animal production because of excretions of N and P. Therefore, any grain processing technique that reduces nutrient excretion has value to the swine industry. We should note that the effects of mill type and particle size on fecal excretion of DM were not independent (mill type × particle size interaction, P<.05); the improvement was markedly greater when particle size was decreased from 800 to 400 µm in the hammermill vs the roller mill.

In conclusion, increased particle size uniformity and using a roller mill to grind grain improved nutrient digestibility in diets. Also, these data make it difficult to attribute the benefits in nutrient digestibility from fine grinding of cereal grains to decreased mean particle size alone, because increased uniformity of particle size was a natural correlate to decreased mean particle size. Finally, it seems likely that the benefits of decreased mean particle size and increased uniformity of particle size may not be independent of mill type used to process the grain, an effect that may be related to particle shape. Further research is needed to verify this observation.

Table 2. Effects of Mill Type on Processing Characteristics when Milling Corn to Intermediate and Small Particle Sizes

	Hammermill		Roller Mill	
Item	800	400	800	400
<u>Grain characteristics</u>				
Mean particle size, µm	826	419	793	415
Variation in particle size, s_{gw}	2.5	1.7	2.0	1.9
Surface area, cm^2/g	82.5	126.8	73.0	133.3
Milling energy, kilowatt h/ton	4.2	11.7	3.9	8.9
Milling production rate, tons/h	4.3	2.2	1.9	1.2
Standardized production rate, lb/horsepower hour[b]	287	147	380	160
<u>Diet characteristics</u>				
Mean particle size, µm	860	558	758	543
Variation in particle size, s_{gw}	2.3	1.6	1.9	1.7
Surface area, cm^2/g	75.2	90.2	73.0	95.2

[a] Values are the percentage of a .22 lb sample retained on top of sieves after 15 min of shaking on a Ro-Tap® shaker.

[b] Standardized production rate = milling production rate/horsepower of mill.

Table 3. Effects of Mill Type and Particle Size on Growth Performance and Digestibility, Intake, and Excretion of Nutrients in Finishing Pigs

	Hammermill		Roller Mill		
Item	800	400	800	400	CV
<u>Pig performance[a]</u>					
ADG, lb/d	2.05	2.13	2.11	2.04	4.1
ADFI, lb/d[g]	7.23	6.91	7.26	6.68	3.6
F/G[g]	3.53	3.24	3.44	3.27	3.3
<u>Apparent digestibility, %[b]</u>					
DM[ehj]	82.5	86.0	86.6	87.3	.9
N[dh]	72.1	80.1	76.0	82.6	2.4
GE[ehj]	81.2	86.7	85.9	87.7	1.4
<u>Intake of digestible nutrients[b]</u>					
DM, lb/d[f]	5.37	5.34	5.66	5.25	3.4
N, lb/d[c]	.105	.112	.114	.115	3.9
GE, Mcal/d	10.54	10.83	11.30	10.71	3.6
<u>Fecal excretion, lb/d[b]</u>					
DM[ehi]	1.14	.87	.87	.77	7.2
N[ch]	.041	.028	.036	.024	10.0

[a] A total of 128 pigs (eight pigs/pen and four pens/treatment) with an avg initial body wt of 122 lb and an avg final body wt of 249 lb.

[b] A total of 64 pigs (four pigs/pen and four pens/treatment).

[cde] Hammermill vs roller mill ($P<.05$, $P<.01$, and $P<.001$, respectively).

[fgh] 800 vs 400 µm ($P<.05$, $P<.01$, and $P<.001$, respectively).

[ij] Hammermill vs roller mill × 800 vs 400 µm ($P<.05$ and $P<.01$, respectively).

DO DIETARY BUFFERS IMPROVE GROWTH PERFORMANCE OR NUTRIENT DIGESTIBILITY OR DECREASE STOMACH ULCERS IN FINISHING PIGS?

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Summary

The effects of supplemental buffers in finely ground diets were determined in two experiments. In Exp. 1, 128 pigs (123 lb average initial body wt) were fed a corn-soybean meal-based diet (488 µm mean particle size for corn) for 66 d. Treatments were a control and 1, 2, or 3% added sodium bicarbonate ($NaHCO_3$). Average daily gain, dressing percentage, and plasma urea N concentration decreased as the concentration of $NaHCO_3$ in the diet was increased. However, the reduction in average daily gain occurred only at the 2 and 3% additions. Feed intake, feed/gain, backfat thickness, stomach ulceration score, stomach keratinization score, and blood gases (pH and HCO_3^-) were not affected by treatment. In Exp. 2, 120 pigs (121 lb average initial body wt) were fed a pelleted wheat-soybean meal-based diet (355 µm mean particle size for the wheat) during a 64-d growth assay. Treatments were: 1) control; 2) 1% added $NaHCO_3$; and 3) 1% added potassium bicarbonate ($KHCO_3$). Average daily gain, feed intake, feed/gain, backfat thickness, stomach keratinization score, plasma urea N concentration, and digestibilities of dry matter and nitrogen were not affected by treatment. However, addition of $NaHCO_3$ and $KHCO_3$ tended to decrease the incidence of ulcers and increased the digestibility of gross energy. These data indicate that a 1% addition of either $NaHCO_3$ or $KHCO_3$ may help to reduce the severity of gastric ulcers in finishing pigs without adversely affecting growth performance or nutrient digestibility.

(Key Words: Finishing, Stomach, Buffers, Particle Size.)

Introduction

The effects of buffers, such as sodium ($NaHCO_3$) or potassium ($KHCO_3$) bicarbonate, on growth performance and nutrient digestibility in pigs are not fully understood. Some researchers have reported increased average daily gain (ADG) and nutrient digestibility in pigs fed lysine-deficient diets supplemented with $NaHCO_3$ or $KHCO_3$. However, others have reported no improvement in rate of gain or nutrient digestibility with supplementation of these buffers. Some researchers have suggested that a relationship exists between decreased pH in the esophageal region of the stomach and increased ulcerations; thus, buffers could help to neutralize the acidity of the stomach and decrease the incidence of ulcers. The experiments reported herein were conducted to determine the effects of dietary buffers ($NaHCO_3$ and $KHCO_3$) on growth performance, carcass characteristics, stomach morphology, nutrient digestibilities, and blood components in finishing pigs.

Procedures

Experiment 1. One-hundred twenty-eight crossbred finishing pigs (123 lb initial body wt) were used to determine differences in growth performance, stomach mor-

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phology, and blood chemistry with diets having various concentrations of $NaHCO_3$. The pigs were housed in a modified open-front building (four barrows and four gilts per pen), with 50% solid concrete and 50% concrete slat flooring. Each pen (6 ft x 16 ft) had a two-hole self-feeder and a nipple waterer to allow ad libitum consumption of feed and water. There were four pens per treatment. Treatments were a control with no buffer, and 1, 2, or 3% added $NaHCO_3$ in a randomized complete block design, with initial body wt as the blocking criterion. The diets (Table 1) were corn-soybean meal-based; formulated to .65% lysine, .65% Ca, and .55% P; and met or exceeded National Research Council recommendations for all nutrients. The corn was finely ground (488 µm) in a hammermill with screen openings of 1/16 in.

Pigs and feeders were weighed at initiation and conclusion of the growth assay to determine growth rate (ADG), feed intake (ADFI), and feed/gain (F/G). Two blood samples were collected from each barrow on d 50. One sample was immediately analyzed for pH and HCO_3^- using an automated blood pH-gas analyzer, and plasma from the other sample was analyzed for urea N concentrations.

When pigs in a weight block averaged 250 lb, the entire group was removed from the growth assay. Two blocks reached the end weight on d 63 and two on d 69 of the experiment. The barrows were slaughtered at a commercial slaughter facility, and hot carcass weight was recorded for calculation of dressing percentage. Last rib backfat thickness was measured with a ruler on each half of the split carcass at the midline. Stomachs were collected and scored for severity of ulcers and keratinization. The scoring system used for ulcers was 1 = normal stomach, 2 = erosion, 3 = ulcer, and 4 = severe ulcer. The scoring system used for keratinization was 1 = normal, 2 = mild parakeratosis, 3 = moderate parakeratosis, and 4 = severe parakeratosis.

Experiment 2. One-hundred twenty crossbred finishing pigs (121 lb initial body wt) were fed diets with different buffers in an attempt to determine further the effects of buffering agents on growth performance, carcass characteristics, stomach morphology, nutrient digestibilities, and blood chemistry. Housing and management were the same as described for Exp. 1, with the exception that each pen in Exp. 2 had five barrows and three gilts. Treatments were a control with no buffers added, 1% added $NaHCO_3$, or 1% added $KHCO_3$. The diets (Table 1) were wheat-soybean meal-based; formulated to .65% lysine, .65% Ca, and .55% P; and met or exceeded National Research Council recommendations for all nutrients. Wheat was used because it is more ulcerogenic than corn; thus, the effects of buffers on the incidence of gastric lesions could be defined more clearly. The wheat was ground to a mean particle size of 355 µm, and the diets were pelleted.

Growth rate, ADFI, and F/G were determined as described in Exp. 1. From d 28 to 33, pigs were fed a diet with .20% chromic oxide. Grab samples of feces were collected from three barrows and two gilts in each pen on d 33. The fecal samples were dried, and digestibilities of dry matter (DM), nitrogen (N), and gross energy (GE) were determined using the indirect ratio method with chromic oxide as the indigestible marker. Blood samples were collected and analyzed as described in Exp. 1.

Termination of the growth assay (56 d for one weight block, 62 d for two weight blocks, and 69 d for two weight blocks) and collection of stomach tissues were as described in Exp. 1. The carcasses were skinned prior to weighing; therefore, the carcass weights were adjusted to skin-on hot carcass weights using the Farmland Foods (Crete, NE) adjustment factor (HCW ÷ .91). Tenth rib fat thickness was measured 2 in from the midline using a Fat-O-Meter® probe and adjusted to skin-on fat thickness by adding .1 in to the probe reading. In addition, a 2 in-thick loin chop (10th rib) was removed from the chilled carcasses of two pigs per pen, and water holding capacity of the longissimus muscle was determined at 48 h postmortem.

Results and Discussion

Experiment 1. Growth rate decreased (linear effect, $P<.01$) and ADFI tended to decrease with increasing levels of $NaHCO_3$ in the diet, but only with the 2 and 3% additions (Table 2). Efficiency of gain was not affected by addition of $NaHCO_3$. The decreased growth performance of pigs given the 2% and 3% $NaHCO_3$ treatments (140 and 181 meq/lb of diet, respectively) indicated that the pigs may have been in an alkalotic state.

Last rib backfat thickness was not affected by treatment, but a linear decrease in dressing percentage resulted from increased concentrations of $NaHCO_3$ ($P<.05$). Two more pigs had normal stomachs in the 1% $NaHCO_3$ treatment group (10 of 16) compared to the control group (8 of 16), but no differences were observed for the mean ulceration or keratinization scores.

No differences in pH and HCO_3^- concentrations of blood were observed. However, plasma urea N concentrations decreased (linear effect, $P<.01$) as supplemental $NaHCO_3$ was increased. The factors regulating acid-base balance and amino acid metabolism are complex, and whether the differing urea N concentrations were a result of changes in amino acid metabolism or differing feed intakes is unclear.

Experiment 2. Average daily gain, ADFI, F/G, tenth rib fat depth, dressing percentage, and water holding capacity of the longissimus were not affected by 1% additions of either $NaHCO_3$ or $KHCO_3$ (Table 3). Thus, as in Exp. 1, inclusion of 1% alkaline salts did not decrease growth performance or carcass merit. However, pigs fed the bicarbonate sources showed a trend for reduced stomach ulcer scores ($P<.10$). This difference resulted from fewer pigs developing ulcers (four vs seven for the buffered and control treatments, respectively) and agrees with the lower number of ulcers in pigs fed the 1% $NaHCO_3$ treatment in Exp. 1.

Apparent tract digestibilities of DM and N were unaffected by treatment. However, energy digestibility was increased ($P<.05$) by addition of the bicarbonates, and more so by $KHCO_3$ than $NaHCO_3$ ($P<.10$).

Blood HCO_3^- increased ($P<.05$) with the addition of the alkaline salts; however, blood pH and plasma urea N concentrations were unaffected. Other researchers have reported increased blood HCO_3^- in pigs and chicks when alkaline salts were added to their diets. However, the lack of effects by the treatments on other blood measurements in our experiment indicated that the pigs maintained acid-base homeostasis with 1% addition of $NaHCO_3$ and $KHCO_3$.

In conclusion, esophagogastric ulcers are becoming of more concern with advances in grain processing techniques such as fine-grinding and extrusion. Implementation of these techniques improves feed efficiency, but is limited because of their ulcerogenic effects. A diet supplement that would allow swine producers to capitalize on feed efficiency improvements without compromising growth performance and health status of pigs would be beneficial. Alkaline salts may ameliorate the ulcerogenic effects of finely ground diets, but our data indicated minimal benefits to growth performance. Further research is warranted, especially in swine herds with frequent incidence of gastric lesions.

Table 1. Composition of Diets[a]

Item	Experiment 1 ($NaHCO_3$, %)				Experiment 2		
	Control	1	2	3	Control	$NaHCO_3$	$KHCO_3$
Ingredients, %							
Corn	82.95	81.87	80.79	79.69	—	—	—
Wheat (hard red winter)	—	—	—	—	88.39	88.39	88.39
Soybean meal (48% CP)	14.20	14.28	14.35	14.44	8.03	8.03	8.03
Monocalcium phosphate	1.08	1.08	1.09	1.10	.82	.82	.82
Limestone	1.02	1.02	1.02	1.02	1.10	1.10	1.10
Salt	.25	.25	.25	.25	.25	.25	.25
Vitamins and minerals[b]	.40	.40	.40	.40	.25	.25	.25
Antibiotic[c]	.10	.10	.10	.10	.10	.10	.10
Lysine HCl	—	—	—	—	.06	.06	.06
$NaHCO_3$	—	1.00	2.00	3.00	—	1.00	—
$KHCO_3$	—	—	—	—	—	—	1.00
Solka floc	—	—	—	—	1.00	—	—
Electrolyte balance, meq/lb[d]	80	108	140	181	61	101	105

[a] Diets were formulated to .65% lysine, .65% Ca, and .55% P.

[b] Exp. 1: old KSU vitamin mix (.25%), old KSU mineral mix (.10%), and old KSU selenium mix (.05%); Exp. 2: KSU vitamin mix (.15%), and KSU mineral mix (.10%).

[c] Antibiotic supplied 100 g/ton chlortetracycline.

[d] Electrolyte balance calculated as meq Na + meq K - meq Cl.

Table 2. Effects of Sodium Bicarbonate on Growth Performance, Stomach Morphology, and Blood Chemistry in Finishing Pigs (Exp. 1)[a]

		$NaHCO_3$, %			
Item	Control	1	2	3	CV
ADG, lb[c]	1.99	2.01	1.92	1.85	3.2
ADFI, lb	6.51	6.51	6.49	6.18	4.0
F/G	3.27	3.24	3.38	3.34	3.4
Fat thickness, in	1.26	1.30	1.23	1.27	6.4
Dressing percentage, %[b]	75.1	74.4	74.7	74.3	.5
Stomach ulcers[d]	2.00	1.75	2.06	2.02	21.1
Stomach keratinization[e]	3.44	3.50	3.27	3.80	4.1
Whole blood					
pH	7.32	7.34	7.31	7.36	.4
HCO_3^-, mmol/L	35.4	36.2	36.5	34.3	4.7
Plasma urea N, mg/100 mL[c]	15.6	14.5	12.6	12.5	9.7

[a] A total of 128 pigs (eight pigs/pen and four pens/treatment) with an avg initial body wt of 123 lb and an avg final body wt of 250 lb.

[bc] Linear effect of $NaHCO_3$ addition ($P<.05$ and $P<.01$, respectively).

[d] Scoring system: 1 = normal, 2 = erosion, 3 = ulcer, and 4 = severe ulcer.

[e] Scoring system: 1 = normal, 2 = mild, 3 = moderate, and 4 = severe.

Table 3. Effects of Sodium Bicarbonate and Potassium Bicarbonate on Growth Performance, Stomach Morphology, Digestibility of Nutrients, and Blood Chemistry in Finishing Pigs (Exp. 2)[a]

Item	Control	1% $NaHCO_3$	1% $KHCO_3$	CV
ADG, lb	2.03	2.00	2.00	2.7
ADFI, lb	6.44	6.50	6.42	3.4
F/G	3.17	3.25	3.21	3.0
Fat thickness, in	.98	1.01	.94	7.0
Dressing percentage, %	70.6	71.3	70.8	1.2
Water holding capacity[b]	.468	.473	.474	6.2
Stomach ulcers[ce]	2.24	1.89	1.96	11.2
Stomach keratinization[d]	2.64	2.52	2.42	8.6
Apparent nutrient digestibility, %				
DM	85.2	85.6	85.8	.8
N	85.3	85.2	85.6	1.2
GE[fg]	85.6	86.3	86.4	.7
Whole blood				
pH	7.32	7.33	7.34	.4
HCO_3^-, mmol/L[f]	34.6	35.7	35.6	1.6
Plasma urea N, mg/100 mL	20.9	23.3	21.7	8.2

[a] A total of 120 pigs (eight pigs/pen and five pens/treatment) with an avg initial body wt of 121 lb and an avg final body wt of 250 lb.

[b] Expressed as a ratio of meat film area to total area [i.e., muscle area ÷ (fluid + muscle area)], with a smaller value representing greater water holding capacity.

[c] Scoring system: 1 = normal, 2 = erosion, 3 = ulcer, and 4 = severe ulcer.

[d] Scoring system: 1 = normal, 2 = mild, 3 = moderate, and 4 = severe.

[ef] Buffer vs no buffer ($P<.10$ and $P<.05$, respectively).

[g] $NaHCO_3$ vs $KHCO_3$ ($P<.10$).

EFFECTS OF CELLULASE ENZYME AND A BACTERIAL FEED ADDITIVE ON THE NUTRITIONAL VALUE OF SORGHUM GRAIN FOR FINISHING PIGS

I. H. Kim, J. D. Hancock, R. H. Hines,
and C. R. Risley[1]

Summary

One hundred and twenty-eight finishing pigs (113 lb average initial body wt) were used to determine the effects of adding cellulase enzyme and *Bacillus* bacteria to sorghum-based diets on growth performance, carcass merit, and nutrient digestibility in finishing pigs. Treatments were: 1) corn-soybean meal-based positive control; 2) sorghum-soybean meal-based negative control; 3) Diet 2 with cellulase; and 4) Diet 2 with a bacterial feed additive (i.e., a mixture of *Bacillus licheniformis*, *Bacillus subtilis*, and *Bacillus pumilus*). There was a trend for greater average daily gain in pigs fed corn vs the sorghum treatments from d 0 to 28, but there was no effect of treatment on overall average daily gain (i.e., d 0 to 63). Overall feed consumption was not affected by treatment, but pigs fed the corn-based diet had 3% greater efficiency of gain compared to pigs fed the sorghum diets. Dressing percentage was not affected by treatment, but there was a trend for fat thickness at the last rib to be greater for pigs fed corn vs the sorghum treatments. Pigs fed corn had greater apparent digestibilities of dry matter, nitrogen, and gross energy than pigs fed the sorghum treatments. In conclusion, pigs fed the corn-based control diet had greater growth performance but tended to be fatter than pigs fed sorghum. Adding cellulase and the bacterial feed additive did not affect growth performance, carcass merit, or nutrient utilization in finishing pigs.

(Key Words: Bacilli, Enzyme, Performance, Digestibility, Carcass, Finishing.)

Introduction

Corn is the most widely accepted energy source used in livestock feeding. In general, it has a greater concentration of available energy, and, therefore, greater feeding value than other cereal grains. Although the feeding value of sorghum is on average 5% less than that of corn, the hardy nature of sorghum makes it appealing to farmers and livestock producers in the High Plains and Southeastern states of the U.S. and in more arid regions of the world. Thus, a means of improving nutrient utilization from sorghum would be of great benefit. It has been suggested that *Bacillus* organisms improve function of the gastrointestinal tract via reduced numbers of *E. coli* organisms and increased synthesis of volatile fatty acids. As an alternative to use of microbial feed additives, some researchers have suggested that enzyme supplementation can improve nutrient utilization and growth performance. Thus, the objective of the present experiment was to determine if cellulase or bacilli improve the nutritional value of sorghum-based diets for finishing pigs.

Procedures

A total of 128 pigs, with an average initial body wt of 113 lb, was blocked by weight and allotted to four dietary treatments based on sex and ancestry. There

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[1] Chr. Hansen's Biosystems, Inc.

were four barrows and four gilts in each pen and four pens per treatment. The pigs were housed in a modified open-front building with 50% solid concrete and 50% concrete slat flooring. Each pen (6 ft × 16 ft) had a three-hole self-feeder and nipple waterer to allow ad libitum consumption of feed and water. Treatments were: 1) corn-soybean meal-based positive control; 2) sorghum-soybean meal-based negative control; 3) Diet 2 with cellulase; and 4) Diet 2 with a bacterial feed additive (i.e., a mixture of *Bacillus licheniformis*, *Bacillus subtilis*, and *Bacillus pumilus*). All diets were formulated to .70% lysine, .65% Ca, and .55% P (Table 1). The diets were fed in meal form.

On d 44 of the experiment, chromic oxide (.25%) was added to the diets, and after a 4-d adjustment period, fecal samples were collected from two barrows and two gilts per pen, pooled within pen, and frozen. The feces were oven-dried at 122°F for 24 h and ground before chemical analyses. The feed and feces were analyzed for dry matter (DM), nitrogen (N), gross energy (GE), and chromium concentrations to allow calculation of apparent digestibilities of DM, N, and GE with chromium as the indigestible marker.

The pigs were slaughtered when those in the heaviest pen in a weight block reached an average body wt of 250 lb. Dressing percentage and last rib backfat thickness for each pig were adjusted to the average final body wt (using regression analysis) before being pooled within pen. Response criteria were average daily gain (ADG); average daily feed intake (ADFI); feed/gain (F/G); dressing percentage; last rib backfat thickness; apparent digestibilities of DM, N, and GE; and excretion of DM and N in feces. Contrasts used to separate treatment means were: 1) corn-based positive control vs sorghum treatments; 2) sorghum-based negative control vs sorghum-based control with cellulase and bacteria; and 3) cellulase vs bacteria.

Results and Discussion

Average daily gain for d 0 to 28 tended to be greater (P<.10) for pigs fed the corn-based positive control compared to the sorghum-based treatments, and pigs fed corn were 4% more efficient (Table 2). Adding the enzyme and bacteria did slightly increase efficiency of gain compared to the sorghum-soybean meal-based negative control (P<.12). For d 28 to 63, ADG and F/G were not affected by treatment, although pigs fed the sorghum diets ate more feed than pigs fed corn (P<.10). Overall (d 0 to 63) ADG and ADFI were not affected by treatment (P>.15), but pigs fed corn were 3% more efficient (P<.01) than pigs fed the sorghum treatments. Adding the cellulase and bacilli did not improve overall growth performance compared to the sorghum-based negative control (P>.15). Also, no differences occurred in growth performance among pigs fed the enzyme vs the bacteria (P>.48).

Dressing percentage was not affected by dietary treatment (P>.15). However, last rib backfat thickness was affected by treatment (P<.10), with pigs fed corn having .04, .07, and .11 inches greater fat thickness than pigs fed sorghum, enzyme, and bacteria, respectively.

Pigs fed corn had greater digestibilities of DM (P<.05), N (P<.001), and GE (P<.01) than pigs fed sorghum (Table 3). These greater nutrient digestibilities also resulted in 13% less DM and 21% less N excreted in the feces when pigs were fed corn compared to sorghum. Those greater nutrient digestibilities probably contributed to a surplus of circulating energy substrates that resulted in greater fat thickness for pigs fed the corn-based diet. The enzyme and bacteria did not improve nutrient digestibilities compared to the sorghum-based negative control (P>.15). Also, nutrient digestibilities or excretions were not different among pigs fed the enzyme vs bacteria (P>.15).

In conclusion, our data indicated that pigs fed a corn-soybean meal-based diet had improved F/G and nutrient digestibilities, but tended to have greater fat thickness than pigs fed sorghum-soybean meal-based diets. Cellulase and bacilli had no effect on growth performance or nutrient utilization.

Table 1. Composition of Diets[a]

Ingredient, %	Corn-Soy	Sorghum-Soy
Corn	81.30	—
Sorghum	—	81.28
Soybean meal (48% CP)	14.85	14.85
Enzyme premix[b]	—	—
Bacteria premix[c]	—	—
Soybean oil	1.00	1.00
Monocalcium phosphate (21% P)	1.08	1.08
Limestone	1.02	1.02
Vitamins and minerals[d]	.55	.55
Lysine-HCl	.05	.07
Antibiotic[e]	.15	.15
Total	100	100
Calculated Values		
CP, %	14.1	14.4
DE, Mcal/lb	1.58	1.54

[a] All diets were formulated to .70% lysine, .65% Ca, and .55% P.

[b] Supplied 15 mg of enzyme (4.5 filter paper units of activity) per lb of complete diet. Added as .05% of the diet at the expense of sorghum.

[c] Supplied 500 million spores per lb of complete diet. Added as .05% of the diet at the expense of sorghum.

[d] KSU vitamin mix (.15%), KSU mineral mix (.10%), and salt (.3%).

[e] Supplied 150 g chlortetracycline per ton of complete diet.

Table 2. Effects of Cellulase and Bacilli on Growth Performance of Finishing Pigs[a]

Item	Corn-Soy	Sorghum-Soy	Sorghum-Soy + Enzyme	Sorghum-Soy + Bacteria	SE
d 0 to 28					
ADG, lb[b]	1.94	1.83	1.90	1.90	.04
ADFI, lb	6.26	6.22	6.44	6.28	.15
F/G[b]	3.23	3.40	3.39	3.31	.07
d 28 to 63					
ADG, lb	2.23	2.21	2.27	2.25	.06
ADFI, lb[b]	7.76	7.87	8.17	8.16	.15
F/G	3.48	3.56	3.60	3.63	.08
d 0 to 63					
ADG, lb	2.09	2.05	2.12	2.09	.03
ADFI, lb	7.12	7.19	7.45	7.36	.13
F/G[c]	3.41	3.51	3.51	3.52	.03

[a] A total of 128 finishing pigs (eight pigs/pen and four pens/treatment) were fed from an average initial body wt of 113 lb to an average final body wt of 251 lb.
[bc] Corn vs other treatments (P<.10, P<.01, respectively).

Table 3. Effects of Cellulase and Bacilli on Carcass Characteristics and Apparent Nutrient Digestibilities in Finishing Pigs[a]

Item	Corn-Soy	Sorghum-Soy	Sorghum-Soy + Enzyme	Sorghum-Soy + Bacteria	SE
Dressing percentage	71.9	71.1	71.6	71.7	.3
Last rib BF, in[b]	1.30	1.26	1.23	1.19	.1
Apparent digestibility, %					
DM[c]	83.4	80.3	81.2	80.7	.9
N[e]	76.1	65.1	66.8	67.7	1.4
GE[d]	84.3	80.6	81.3	80.9	.8
DM consumed, g/d[f]	2,690	2,610	2,740	2,690	31
N consumed, g/d[dg]	58	50	55	53	1.2
DE consumed, kcal/d[d]	11,897	10,674	11,326	10,846	248
DM excretion, g/d[d]	447	514	515	519	29
N excretion, g/d[e]	14	18	18	17	1.1

[a] A total of 64 finishing pigs (four pigs/pen and four pens/treatment).
[bcde] Corn vs other treatments (P<.10, P<.05, P<.01, P<.001, respectively).
[fg] Sorghum vs enzyme and bacteria (P<.05, P<.10, respectively).

RELATIONSHIP BETWEEN HAM COMPOSITION AND CARCASS COMPOSITION IN FINISHING SWINE

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Summary

The relationship between ham and carcass composition of 120 barrows with an average initial weight of 130 lb was used to develop prediction equations to determine carcass composition based on ham composition. Eighty pigs were slaughtered to determine total body and ham composition. The first half were slaughtered at 230 lb and the second half at 280 lb. Longissimus muscle area, backfat thickness, whole ham weight, and trimmed ham weight of each pig were recorded 24 h following slaughter. The right ham and the right side of each carcass were ground and analyzed for protein, lipid, moisture, and ash contents. A correlation analysis was conducted at each slaughter weight to determine the relationship between total carcass and ham composition. Based on the results of the correlation analysis, we determined that it would be beneficial to run a regression analysis to develop prediction equations for carcass protein, lipid, and moisture contents. The ash content of the carcass did not appear to be highly correlated to any of the variables tested and, thus, a prediction equation for total body ash was not formulated. Using a stepwise regression analysis, the following equations and correlation coefficients were developed to determine total carcass composition at a slaughter weight of 230 lb: 1) carcass moisture = .4019 + .3911 (ham moisture) - .5301 (ham lipid) (R^2 = .73); 2) carcass lipid = .3325 - .3787 (ham moisture) + .7334 (ham lipid) (R^2 = .75); and 3) carcass protein = .1985 + .6757 (ham protein) + .0914 (longissimus muscle area) (R^2 = .49). For pigs fed to the heavier slaughter weight of 280 lb, the prediction equations were: 1) carcass moisture = 1.2852 - 1.0558 (ham lipid) - 5.5573 (ham ash) - .0165 (whole ham weight) (R^2 = .54); 2) carcass lipid = -.1650 + 1.0089 (ham lipid) + .0085 (whole ham weight) (R^2 = .74); and 3) carcass protein = .4528 + 2.6234 (ham moisture) - 1.8241 (ham lipid) - 10.4795 (ham ash) + .4690 (ham protein) (R^2 = .86). These results indicate that ham composition can be used to predict total carcass composition.

(Key Words: Body Composition, Heavy Weight, Carcass.)

Introduction

Recently, swine producers have started to feed their finishing pigs to a heavier market weight. As a general rule, these heavier pigs have a higher percentage of body fat and a lower percentage of protein when an analysis of total carcass composition is conducted. Occasionally, performing an analysis of body composition is important to researchers to help determine the efficiency of the pigs at different market weights and the value of slaughtering pigs at that particular weight. However, to conduct a total carcass composition analysis is time consuming and costly. An entire side of the pig's carcass must be ground to obtain the necessary data. If equations could be developed to predict the total carcass composition based on a smaller portion of the carcass, time and money could be saved.

Therefore, the objective of this experiment was to determine the relationship between ham composition and total carcass composition in finishing pigs slaughtered at 230 and 280 lb.

Procedures

One hundred twenty crossbred barrows (Duroc × Yorkshire × Hampshire) averaging 130 lb were allotted on the basis of weight and ancestry to 40 pens with three pigs per pen. Pigs were housed in a modified open-front building with solid concrete floors. Pigs had ad libitum access to feed and water. Pigs were weighed at 14-d intervals until the mean weight of the pigs in a pen reached 230 lb. At this time, one pig per pen was randomly selected for slaughter and analysis of carcass composition. The other two pigs remained on their experimental treatments until they reached a final mean weight of 280 lb. One of the two remaining pigs was then randomly selected for slaughter and analysis of total carcass composition. Carcasses of pigs slaughtered at 230 and 280 lb were split in half and chilled at 40°C for 24 h. Then, average backfat thickness and longissimus muscle area (LEA) were measured and recorded. The right ham was removed from each pig for evaluation. A whole ham weight was recorded and then the hams were trimmed to approximately .25 in fat thickness and a trimmed ham weight was recorded. The entire right side of each carcass, including the ham, was then briefly frozen, cut into small pieces, and passed twice through a grinder equipped with a 1/8 in plate. A 1 lb sample of the ground ham was obtained for determination of crude protein, lipid, moisture, and ash contents. The ground ham was then mixed with the rest of the ground carcass for 2 min in a twin ribbon mixer, and a 1 lb sample was obtained for determination of total carcass protein, lipid, moisture, and ash contents.

Results and Discussion

A correlation analysis was conducted at each slaughter weight using the following variables: ham moisture, ham protein, ham ash, ham lipid, carcass moisture, carcass protein, carcass ash, carcass lipid, LEA, average backfat, whole ham weight, and trimmed ham weight. With a perfect correlation being equal to 1 or -1, at 230 lb carcass moisture (r = .77) and carcass lipid (r = -.79) contents were both closely correlated to ham protein and to ham lipid (r = -.84 and .85, respectively) (Table 1). Carcass protein content showed the highest correlation to ham protein (r = .66), ham lipid (r = -.64), and ham moisture (r = .61). Carcass ash content did not appear to be highly correlated to any of the variables tested (r<.48). When pigs were slaughtered at 280 lb, carcass moisture was correlated with ham moisture (r = .61) and ham lipid (r = -.63) (Table 2). Carcass lipid content was closely related to ham lipid (r = .85), ham moisture (r =- .84), and average backfat thickness (r = .79). The protein content of the carcass at 280 lb showed a very close correlation to ham moisture content (r = .90), ham lipid content (r = -.88), and ham protein content (r = .84). As at 230 lb, the ash content of the carcass at 280 lb was not highly correlated to any of the variables tested (r<.50).

Based on the results of the correlation analyses, a stepwise regression analysis was performed to develop prediction equations to determine total carcass protein, lipid, and moisture contents from ham composition and standard carcass measurements. Because total carcass ash was not highly correlated to any of the variables tested, no regression equations were developed. The variables used in the regression analysis included: ham moisture, ham protein, ham lipid, ham ash, LEA, average backfat thickness, whole ham weight, and trimmed ham weight. The use of the stepwise procedure in the regression analysis allowed each variable to be tested, and if the variable was significant (P<.15) level, it was included in the equation.

At a slaughter weight of 230 lb, the equations for predicting total carcass moisture and lipid contents were based on ham moisture and ham lipid content. Of the two variables, ham lipid content was the more important, because this variable had an R^2

value of .70 for total carcass moisture and an R² of .73 for total carcass lipid content. The prediction equation derived using both variables was: total carcass moisture = .4019 + .3911 (ham moisture) - .5301 (ham lipid); and total carcass lipid = .3325 - .3787 (ham moisture) + .7334 (ham lipid). When both variables were used in the equations, total carcass moisture had an R² value of .73 and total carcass lipid had an R² of .75. The protein content of the carcass are not predicted as accurately as lipid and moisture. The equation included both ham protein content and LEA, but the R² value was just .49. If only one of these variables is used, ham protein content is better because it provides an R² value of .44. The prediction equation is: total carcass protein = .1985 + .6757 (ham protein) + .0914 (LEA).

When pigs were fed to the heavier slaughter weight of 280 lb, the prediction equation for total carcass moisture included ham lipid and ham ash contents and whole ham weight. Using all three variables in the model gave an R² value of .54. The equation developed was: total carcass moisture = 1.2852 - 1.0558 (ham lipid) - 5.5573 (ham ash) - .0165 (whole ham weight). The prediction equation for carcass lipid content was: total carcass lipid = -.1650 + 1.0089 (ham lipid) + .0085 (whole ham weight). The final prediction equation for carcass protein content developed for pigs at 280 lb was: total carcass protein = .4528 + 2.6234 (ham moisture) - 1.8241 (ham lipid) - 10.4795 (ham ash) + .4690 (ham protein). This model uses four variables with an R² value of .86, but the important variable to include is ham moisture, with an R² value of .82.

Although these prediction equations for total carcass composition are certainly not as accurate as performing the actual chemical analysis, they can provide an estimate for determining carcass composition in the pig. Use of these equations can save the researcher time and money and still provide valuable information.

Table 1. Correlation Coefficient between Ham and Total Carcass Composition for Pigs Slaughtered at 230 lb[a]

Variable	Ham Moisture	Ham Lipid	Ham Ash	Ham Protein	Whole Ham Wt	Trimmed Ham Wt	Average Backfat	LEA
Carcass moisture	.805	-.835	.320	.771	.347	.672	-.616	.617
Carcass lipid	-.799	.853	-.311	-.788	-.305	-.667	.593	-.629
Carcass ash	.327	-.485	-.014	.359	.208	.427	-.419	.345
Carcass protein	.613	-.644	.206	.662	.276	.505	-.401	.528

[a]The correlation analysis is based on carcass and ham data from 40 pigs.

Table 2. Correlation Coefficient between Ham and Total Carcass Composition for Pigs Slaughtered at 280 lb[a]

Variable	Ham Moisture	Ham Lipid	Ham Ash	Ham Protein	Whole Ham Wt	Trimmed Ham Wt	Average Backfat	LEA
Carcass moisture	.620	-.634	-.184	.503	-.084	.251	-.608	.408
Carcass lipid	-.838	.850	-.058	-.716	-.006	-.433	.789	-.550
Carcass ash	.412	-.400	.297	.439	-.122	.127	-.504	.237
Carcass protein	.904	-.811	.025	.839	.106	.550	-.804	.618

[a]The correlation analysis is based on carcass and ham data from 40 pigs.

STATE OF THE KANSAS SWINE INDUSTRY

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Summary

The Kansas hog industry represented 3.8% of U.S. hog production in 1977 and had peak production of nearly 3.4 million head in 1971. Since that time, the industry has declined significantly, representing only 2.5% of U.S. hog production with 2.5 million head produced in 1992. Kansas hog production has declined, while neighboring Nebraska has enjoyed increased production and share of U.S. production. Kansas hog production is also highly concentrated, with the largest 3.5% of producers owning 45.5% of the state's hog inventory. Efforts to identify specific causes and to change the economic environment will be required to reverse the decline in the Kansas swine industry.

(Key Words: Swine Industry Trends, Hog Marketings, Swine Industry Structure.)

Introduction

The size of the Kansas swine industry has declined considerably over the last 15 years. During this time, the share of U.S. hog production represented by Kansas producers dropped from 3.7% in 1978 to 2.5% in 1992. The number of hogs produced in the state has declined by more than 30% since 1980. As a result of this rapid decline in the state's swine industry, increased debate has surfaced regarding why this has occurred and how it might be reversed. This debate has lead to policy proposals such as the recent corporate farming bill that attempts to entice more swine production, slaughtering, and processing to the state. This policy controversy has been emotion laden, with producers and various associations taking strong stances. The purpose of this report is to document some of the important economic trends that have occurred in the Kansas swine industry.

Procedures

Several key trends clearly illustrate the changing size, status, and structure of the Kansas swine industry. Factors selected for summary in this report include number of operations, hogs marketed, marketings per operation, and inventory value of hogs in Kansas. Trends in these data are examined during 1980-92 to determine how operation numbers and value of hogs produced in the state have changed.

Data were also collected on marketings and share of U.S. marketings in Kansas, Nebraska, and North Carolina. Kansas data are compared with Nebraska data because of their proximity and similar type of production environment. Kansas trends are also compared with those of North Carolina, the state with the fastest growing hog production in the U.S.

Finally, the current structure of the Kansas swine industry is examined to show the concentration of hog production in the state. All data summarized in this report

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were collected from U.S. Department of Agriculture publications.

Results and Discussion

Trends in number of hog operations, marketings, and inventory value of hogs in Kansas over 1980-92 are reported in Table 1. The number of operations in the state declined by nearly 60% over the 13-year period from 14,000 to less than 6,000. Nationally, the number of producers declined by 63% over the same time period. The average-sized hog operation in Kansas almost doubled from 1980 to 1992 in terms of number of hogs marketed annually. Hogs marketed annually in Kansas declined from 3.3 million head in 1980 to 2.5 million head in 1992. Total U.S. hog production was about 1.5 million head less in 1992 than 1980. The decline in hog production in Kansas was also associated with a decline in value of hog inventory on farms. In 1980, the total value of inventory on December 1 in Kansas was $123.5 million. This declined to $95.0 million by December 1992.

The majority of the hogs produced annually are raised in north-central and northeastern Kansas. Figure 1 illustrates the location of the 1992 pig crop by county. Of the eight counties with a pig crop larger than 50,000 head in 1992 (in order from largest Washington, Nemaha, Marshall, Clay, Jewell, Pottawatomie, Brown, and Butler), only Butler County is not located near the Kansas-Nebraska border. The northeast and north central regions represented 42% of the state's total pig crop. The important point to learn from this is that the largest portion of hog production in Kansas is in a relatively small geographic region. Because of this geographic concentration, hog production is an important component of local economic prosperity.

Figure 2 illustrates how the number of hogs produced and share of hog production in Kansas has declined relative to Nebraska and North Carolina. While Kansas hog marketings dwindled during the last 10 years, Nebraska and North Carolina both enjoyed dramatic increases in hog production. North Carolina almost doubled hog production from 1980 to 1992. Similarly, Nebraska increased production by 16% during this same period, while Kansas production declined by 24%. Individual state shares of U.S. production show similar trends to production numbers. Kansas has dropped from ranking as the seventh largest hog producing state in the late 1970s to the tenth largest currently.

Part of the discussion surrounding the debate regarding corporate ownership of swine production facilities and hogs in Kansas relates to industry structure. Figure 3 illustrates the current structure of Kansas hog producers. The group of producers with the smallest hog farms (inventory of 1 to 99 head) represents 57% of the hog farms in Kansas. However, this group marketed only 8.5% of the hogs produced in the state in 1992. In contrast, 3.5% of the producers having the largest operations (1,000 head and above) represented 45.5% of 1992 hog production in Kansas. Although some states have much higher levels of producer concentration (e.g., 9.3% of North Carolina producers owned 90% of the inventory in the state in 1992), the concentration in Kansas is similar to that present in the U.S. as a whole.

The trends that have been witnessed recently in Kansas swine production indicate a shrinking absolute and relative industry. The number of producers, hogs marketed, and inventory value have all declined in absolute terms over the last decade. In relative terms, Kansas share of U.S. production has also declined. For the Kansas swine industry to survive, continued debate is needed regarding alternative actions to enhance the economic environment.

Table 1. Number of Hog Operations, Marketings, and Inventory Value of Hogs in Kansas, 1980-92[a]

Year	Number of Operations	Hogs Marketed (1,000 Head)	Marketings per Operation (Head)	Inventory Value of Hogs December 1 ($1,000)
1980	14,000	3,300	236	123,500
1981	13,000	3,069	236	111,510
1982	11,200	2,754	246	141,115
1983	9,400	2,758	293	88,275
1984	8,400	2,612	311	110,400
1985	8,300	2,636	318	99,560
1986	7,000	2,470	353	121,410
1987	6,900	2,289	332	102,225
1988	6,500	2,493	384	93,000
1989	6,800	2,598	382	109,475
1990	6,000	2,467	411	121,500
1991	5,600	2,469	441	92,950
1992	5,700	2,514	441	95,040

[a]Source: U.S. Department of Agriculture.

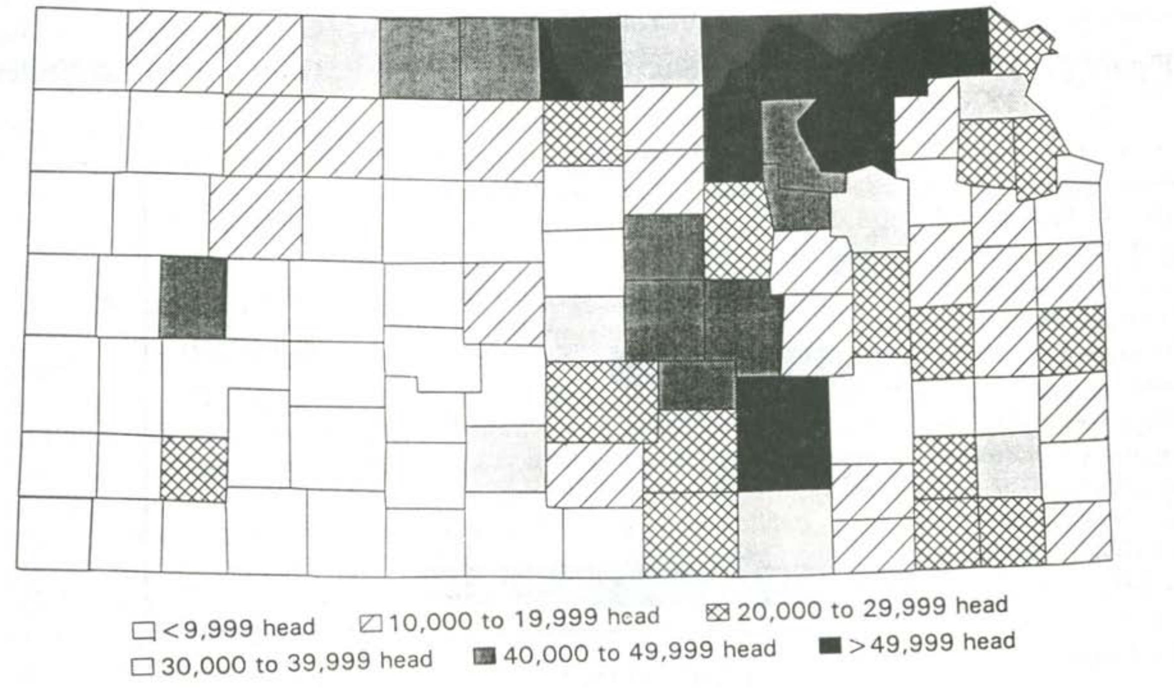

Figure 1. Location of Pig Crop in Kansas by County, 1992. Source: Kansas Agricultural Statistics

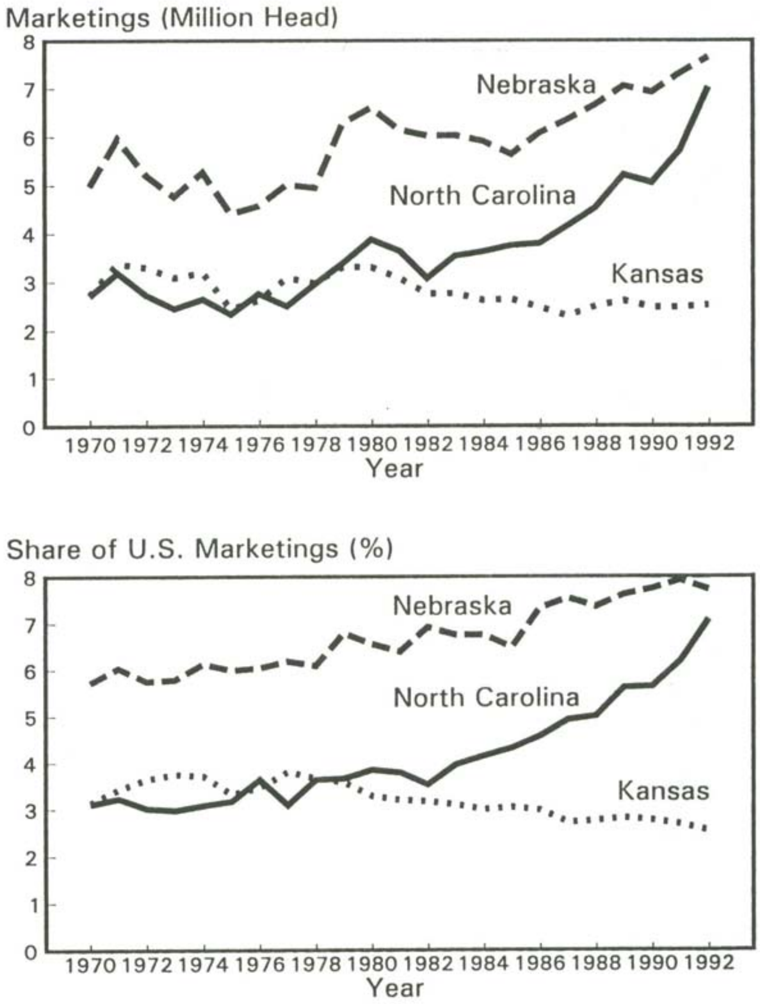

Figure 2. **Hog Marketings and Share of U.S. Hog Marketing, Selected States, 1970-92**

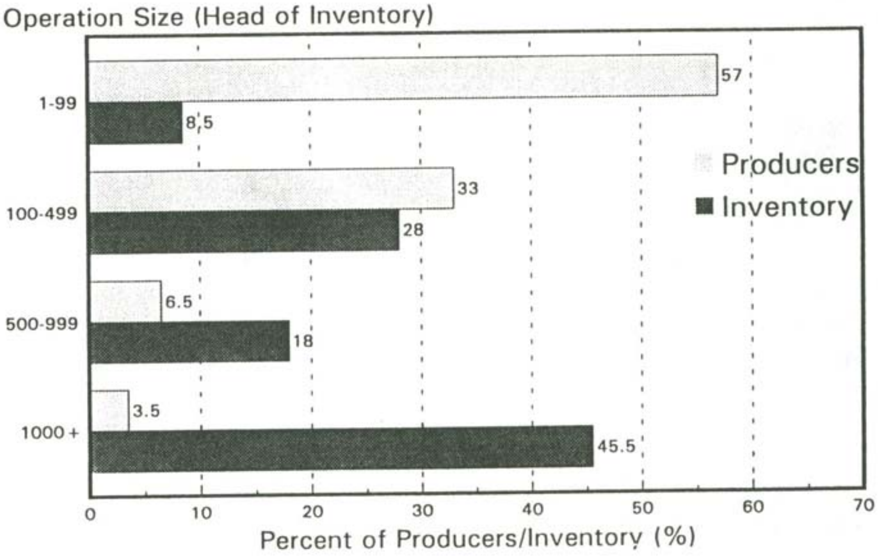

Figure 3. **Number of Hog Operations and Percentage of Inventory by Size in Kansas, 1992**

EVALUATION OF CARCASS MERIT PRICING BY PORK PACKERS

T. C. Schroeder[1]

Summary

Live hog prices must reflect end-use value to convey market information from consumers to producers. Precise end-use value is excessively costly to trace for each carcass given current technology. Pricing structures must be based upon carcass merit information that is correlated with end-use value. This study uses pork carcass cut out data from 794 carcasses to estimate hog carcass values based upon carcass characteristics. Carcass values varied by nearly $20/cwt based on quality differences alone. In addition, considerable differences were present in pricing schedules of different pork packers suggesting that hog producers need to shop around when deciding to which packer they sell their hogs.

(Key Words: Hog Carcass Merit Pricing, Pork Pricing Systems, Packer Pricing.)

Introduction

Consumers are willing to pay for high quality lean meat. However, a recent quality survey found that only 16% of retail pork was "ideal" quality, and over half was "questionable" quality. Producers have direct control over the leanness and yields of pork products that they produce through selection of genetics and production methods. However, these products will be produced only with economic incentives. Swine producers must be paid for desirable carcass traits and receive discounts for hogs possessing undesirable traits. Value-based pricing of hogs, pricing based upon end-use values of carcasses, is one method to help enhance retail pork quality and is a primary goal of the pork industry. The National Pork Producers Council has established live hog pricing guidelines for pork processors to increase conveyance of consumer preferences to hog producers. To ensure that hogs are priced based on end-use value requires purchasing them on a carcass merit basis. The percentage of hogs sold on merit increased from 14% in 1984 to 25% in 1990. Although value-based buying is increasing, most hogs are still purchased without knowledge of specific carcass quality characteristics. This study examined how price structures of pork packers reflect value-based pricing systems.

Procedures

A sample of carcass fabrication yields was acquired from a yield test of 794 carcasses conducted by a midwestern pork packer. Backfat was measured using a Fat-O-Meter, and loin eye areas were physically measured. Carcass values were calculated by multiplying weights of the individual fabricated cuts, fat, lean, trim, skin, and bone for each carcass by their associated U.S. Department of Agriculture prices plus a midwestern packer's overages for the most closely equivalent wholesale products. Individual carcass values were regressed against carcass traits (backfat, loin eye area, weight, weight squared, muscling, and carcass length) to determine how these traits related to carcass value. Packers'

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[1] Department of Agricultural Economics.

pricing schedules were compared with carcass values to determine how closely packers' pricing systems reflected carcass values.

Results and Discussion

Average yields of the major primal cuts from the 794 carcasses are reported in Table 1. Ham, the largest cut, represented almost one-fourth of the carcasses on average; however, this varied from 20% to almost 29%. The total lean cuts of boneless picnic, Boston butt, loin, and ham represented about 58% of the carcass, but again had a wide range of 51% to 65%. Table 1 shows that carcasses vary considerably in fabricated cut yields. The data were not random, they were stratified to cover the range of carcasses typically delivered to packers. Table 2 reports summary statistics of carcass traits. Carcass values averaged $71.80/cwt ranging from $63.23/cwt to $80.12/cwt (prices were for the week ending September 13, 1991, the period for which packer price schedules were obtained). Assuming 74% dressing percentage, this $17/cwt range in carcass values transfers to more than a $12.50/cwt live hog price range. Although this represents value differences across a wide range of carcasses, it nonetheless portrays the importance of merit pricing.

Table 3 shows how hog carcass values change as carcass weight and backfat thickness vary (carcass length was allowed to vary in relation to carcass weight according to the average relation between weight and length), holding other factors constant. The base carcass is assumed to be 185 lb carcass with 1.2 in backfat. Premiums of 3% to 6% are warranted for lighter-weight lean hogs (with the exception of excessively light-weight carcasses). Discounts exceed 5% as carcass weight increases beyond 205 lb and backfat depth increases to 1.6 in or more. This is similar to, and reconfirms, the pork value guide published by the National Pork Producers Council.

Price structures of several packing firms were collected from data surveyed by Clark Consulting International Inc. Packers were asked to value carcasses of 240 lb hogs with 74% dressing (constant 177.6 lb carcass) with varying backfat and loin eye area and a base live hog price of $50/cwt. These prices are packer reported and do not necessarily reflect actual prices paid.

Figures 1 through 3 illustrate three packers' actual and expected pricing structures (based on estimated value) as backfat varies. These three pricing systems are presented here as examples showing that although some packers' pricing schedules were highly consistent with estimated carcass values (Figure 2), others were not (Figure 1 and 3). As can be seen, packer one (Figure 1) has a step function pricing schedule that tends to value carcasses in a discrete manner. This results in undervaluing the leanest hogs with less than 0.6 in backfat and overvaluing 1 to 1.2 in backfat hogs. Overall, the root mean squared error between the modeled and actual values for packer one was $1.86/cwt (1.53% of the mean price). Packers two's pricing structure was considerably more consistent with the modeled structure. The root mean squared error between actual and modeled carcass values for packer two was less than $0.90-/cwt (less than 0.80% of the mean price). Packer three had the most diverse pricing structure relative to estimated value with a root mean squared difference of $4.72/cwt (3.89% of the mean). Packer three's (Figure 3) premiums for lean hogs were considerably (as much as $4/cwt or more) higher than the estimated values and his discounts for lean hogs were considerably lower. This packer's pricing structure certainly favors leaner hogs more than the typical wholesale market would suggest, although premiums for the leanest carcasses (0.4 in backfat) are less relative to the modeled values than premiums for moderately lean carcasses (0.6 to 1.0 in backfat).

Clearly, hog producers need to shop around, to the extent that packer availability allows, given significant differences in packers' pricing schedules. Producers who produce high-yielding lean hogs benefit from searching for packers that pay highest premiums for this trait. Rigid step-function pricing schedules used by some packers can work to either the advantage or disadvantage of the producer, depending upon the type of hogs produced.

Table 1. Summary Statistics of Hog Carcass Primal Yields

Primal	Average	Standard Deviation	Minimum	Maximum
	- - - - - - - - - - - - -	% of Carcass	- - - - - - - - - - - - -	
Boneless picnic	7.13	0.74	4.72	9.82
Boston butt	8.04	0.74	5.30	10.33
Loin	18.27	1.70	13.98	24.33
Ham	24.47	1.15	20.26	28.92
Skinless belly	15.22	1.72	9.66	19.76
Picnic cushion	1.28	0.19	0.75	1.88
Sparerib	3.72	0.39	2.59	5.39
Jowl	1.83	0.41	0.44	3.47
Total lean[a]	57.92	2.80	51.32	65.33

[a] Total lean = boneless picnic + Boston butt + loin + ham.

Table 2. Summary Statistics of Selected Hog Carcass Attributes

Carcass Attribute	Average	Standard Deviation	Minimum	Maximum
Value[a] ($/cwt)	71.80	3.53	63.23	80.12
Cold Carcass Weight (lb)	185.56	26.58	119.04	273.06
Last Rib Fat (in)	1.25	0.31	0.50	2.20
Carcass Length (in)	31.74	1.61	27.30	36.70
Loin Eye Area (sq in)	5.63	1.21	2.55	11.05

[a] Estimated wholesale value using prices from week ended September 13, 1991.

Table 3. Carcass Value with Varying Backfat and Weight

Carcass Length (in)	Cold Carcass Weight (lb)	Last Rib Backfat Thickness (in)							
		0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
		- - - - - - - Carcass Value as a Percentage of Base (%) - - - - - -							
30	145	109	107	105	104	102	100	99	97
30	155	108	106	104	103	101	100	98	96
31	165	107	105	103	102	100	99	97	96
31	175	105	104	102	101	99	98	96	95
32	185	104	103	101	BASE	99	97	96	94
32	195	103	102	100	99	98	96	95	94
33	205	102	101	99	98	97	96	94	93
33	215	101	100	98	97	96	95	94	93
34	225	99	98	97	96	95	94	93	92
34	235	98	97	96	95	94	93	92	91

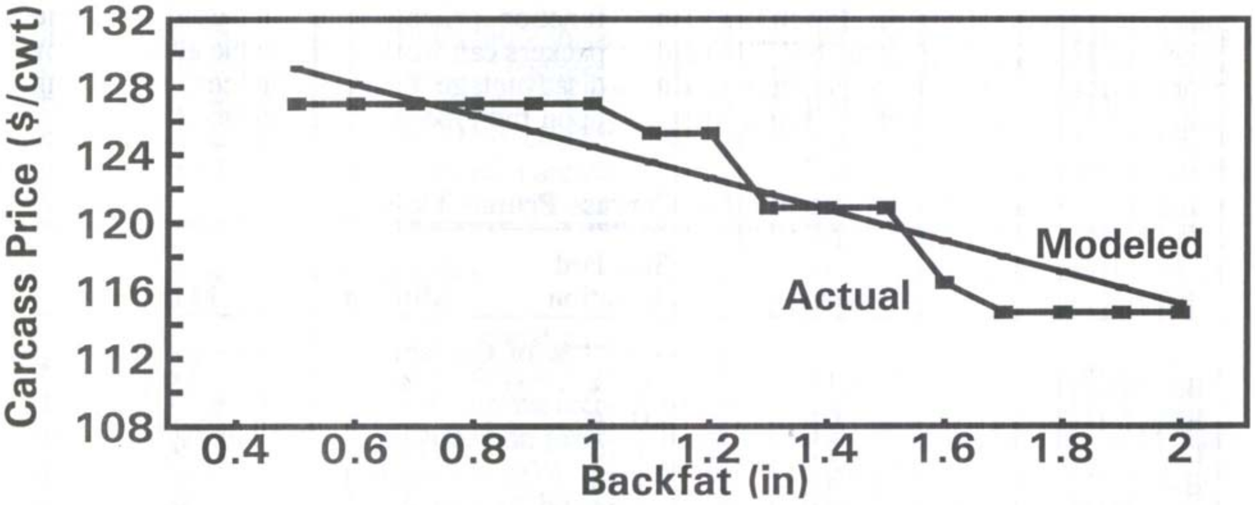

Figure 1. Comparison of Actual and Modeled Hog Carcass Pricing Structure, Packer One

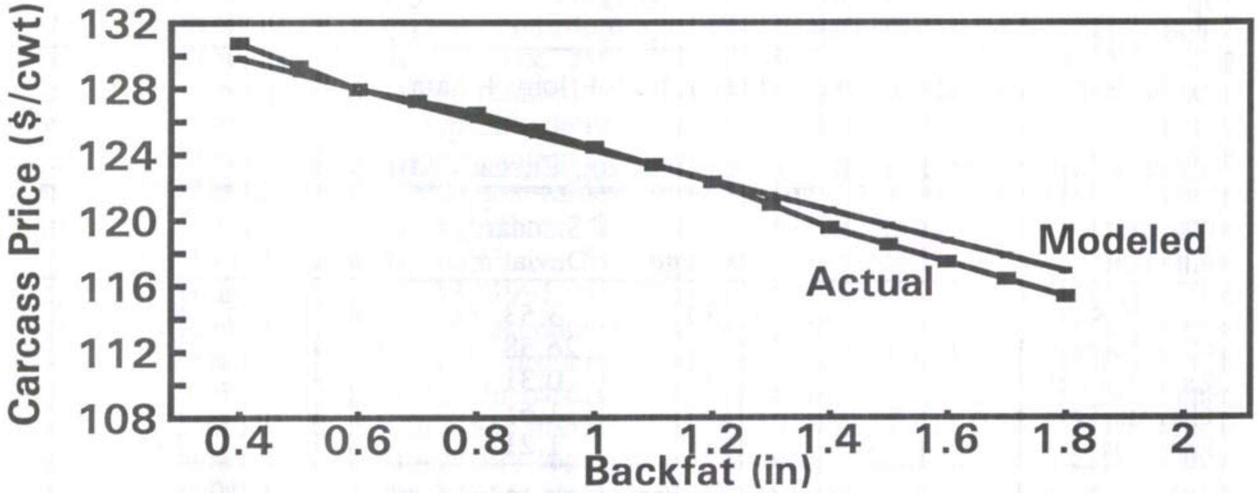

Figure 2. Comparison of Actual and Modeled Hog Carcass Pricing Structure, Packer Two

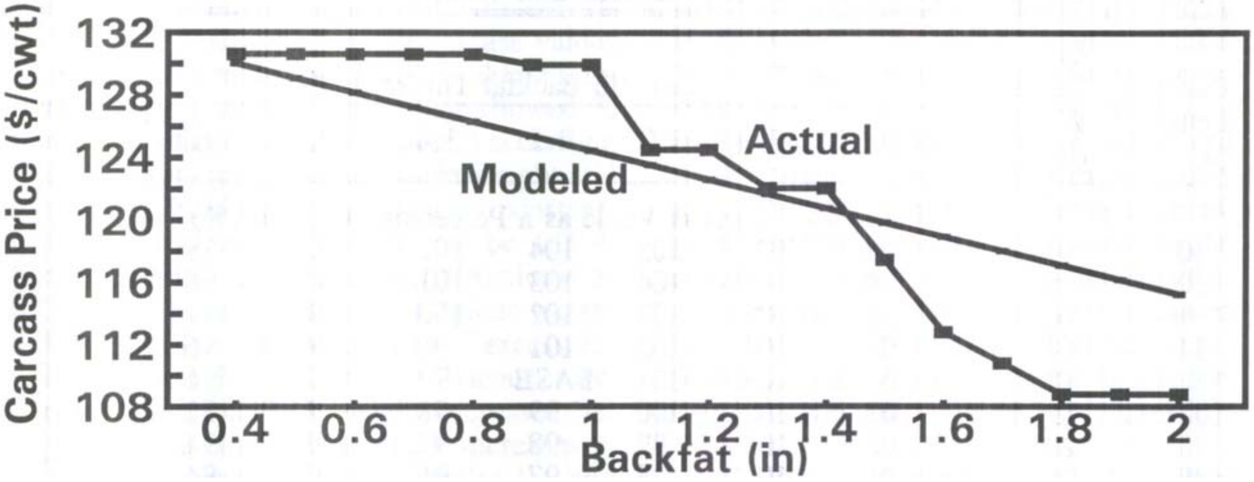

Figure 3. Comparison of Actual and Modeled Hog Carcass Pricing Structure, Packer Three

THE RELATIONSHIP AMONG LIVE HOG, CARCASS, AND WHOLESALE CUT PRICES

G. L. Keeler[1], M. R. Langemeier[2], M. D. Tokach,
R. D. Goodband, and J. L. Nelssen

Summary

This study examined the relationship between live and carcass prices and the seasonality of live, carcass, and wholesale cut prices. Results using Omaha live prices suggested a unidirectional relationship between live and carcass prices, with farm prices leading carcass prices by 3 weeks. In contrast, the results generated using live prices from the St. Joseph terminal market suggested a bidirectional relationship. Live and carcass prices from 1987 to 1992 were found to be highly correlated. The average monthly price spread between the Omaha live price and the USDA carcass price ranged from $14.02 to $23.18 cwt, with an average spread of $17.53 cwt. The spread has changed only marginally from 1987 to 1992. Loin prices were found to follow the seasonal price pattern of live and carcass prices, except that they declined to a greater degree in October and November. Ham prices also followed the seasonal price trend of live and carcass prices, except that they increased to a greater extent during Thanksgiving and Christmas. The increased support of ham prices in the fall tended to offset the seasonal weakness in loin prices. Seasonality of spare rib prices was evident, with the high prices occurring during the outdoor cooking season (May, June, and July). Boston butt prices followed the seasonal pattern of live and carcass prices.

(Key Words: Carcass Price, Live Price, Wholesale Price, and Seasonality.)

Introduction

As producers adopt lean value marketing strategies, they have increased interest in the relationship between live and carcass prices. Previous studies at Kansas State University have found that live prices unidirectionally cause retail and wholesale carcass prices. Furthermore, these previous studies have suggested that the farm price leads the carcass price by 3 to 5 weeks. However, as more pigs are purchased on a lean value basis and as data gathering technology improve, the lag time between live price and carcass price would be expected to disappear or at least decrease.

The seasonality of live prices for market hogs is well documented. Producers are aware that live prices peak during the summer and are lowest in the fall of the year. However, the seasonal patterns of carcass prices and resulting wholesale cut prices have not been well documented. Understanding the seasonal pattern of carcass and wholesale cut prices is important to producers selling on a lean value basis, because gross returns are directly dependent on fluctuations in carcass prices.

Therefore, the objectives of this study were 1) to determine the relationship between live hog and carcass prices and 2) to determine the seasonality of wholesale cut prices and their relationship to carcass and live hog prices.

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Procedures

This study used live hog, carcass, and wholesale cut prices. Live hog prices for this study were obtained for the Omaha and St. Joseph terminal markets from the United States Department of Agriculture, Agricultural Marketing Service (USDA, AMS). US#1 and US#2 carcass and wholesale cut prices were obtained from issues of the USDA Wholesale Price Sheet. The US #1 and US #2 carcass prices were averaged to obtain the carcass prices used in the analyses.

Weekly live and carcass prices for the 1987 to 1992 period were used to test for directional causality. The Granger causality test was used for this analysis involving first-differences of the data. Each price series (y) was regressed on lagged values of that price series and lagged values of the other price series of interest. Specifically, each live price was regressed on lagged values of that live price and lagged values of the carcass price. In addition, the carcass price was regressed on lagged carcass prices and lagged live prices. Separate results were generated for Omaha and St. Joseph.

An F-test was used to compare the reduced form (y regressed on lagged y) and the full models (y regressed on lagged x and lagged y) for the live price series. An F-test also was used to compare the reduced form and full models for carcass prices. Large F statistics indicate causality. Causality can take one of three forms. First, it can be unidirectional (i.e., only one F statistic is significant). Second, it can be bidirectional (i.e., both F statistics are significant). Third, there may be no relationship between variables. For this case, neither F statistic would be significant. The lags were selected using Akaike's Information Criteria (AIC) with the same lag for both x and y in the individual regressions.

Average monthly prices from January, 1987 to December, 1992 were reviewed to determine seasonality in live, carcass, and wholesale cut prices. Seasonal trends were computed and analyzed using the mean monthly price for the 6-year period. For example, the average monthly prices for January of each year were summed and divided by six to determine the mean monthly price. Correlation analysis was conducted using procedures described by SAS (1988) to determine the relationship between live price, carcass price, and prices of each wholesale cut. Wholesale cuts used in the analysis included: loins, hams, butts, spareribs, bellies, trim 72% (trim that can be tested by the USDA to be 72% lean), trim 42% (trim that can be tested by the USDA to be 42% lean), and jowls. Picnics, pork fat, feet, and tails were not included in the wholesale cut analyses because of infrequency of price quotations for these cuts. Correlation analysis was also used to determine the relationship between weekly live, carcass, and wholesale cut prices in 1992.

Results and Discussion

Relationship between Live Prices and Carcass Prices. The Granger causality test results are reported in Table 1. The results differ between the two live price series. The results for Omaha indicate a unidirectional causation from farm to wholesale carcass. In addition, the Omaha results suggest that farm price changes led wholesale price changes by 3 weeks. The results with respect to Omaha live prices are similar to those obtained by previous research conducted at Kansas State University; however, the lag length is 1 week shorter.

The results using live prices for St. Joseph suggest a bidirectional relationship between live prices and wholesale prices. In other words, there is significant feedback between these two price series.

Thus, causality results from the two terminal markets are mixed or inconclusive. The Omaha results suggest that wholesale prices lag behind live prices by 3 weeks. In other words, live prices lagged 1, 2, and

3 weeks would be useful in comparisons between live and carcass prices. In contrast, the St. Joseph results suggest that lagged live prices are not needed in comparisons between live and carcass prices. For ease of understanding, we chose to compare contemporaneous live and carcass prices below. These comparisons would be consistent with the results for the St. Joseph terminal market.

Average monthly live prices for Omaha and St. Joseph were highly correlated (P<.0001; r=.99). This would be expected because the markets are in close proximity to each other. Also, buyers from the same plants compete for hogs at both of these terminal markets. The difference in the mean price between Omaha and St. Joseph was $0.27 cwt. The mean Omaha price was $48.36 cwt, and the mean at St. Joseph was $48.09 cwt. Average monthly live prices for Omaha ranged from $37.66 to $63.54 cwt, with a standard deviation of $6.62 cwt. St. Joseph's average monthly live price ranged from $37.24 to $62.65 cwt, with a standard deviation of $6.65 cwt.

Average monthly Omaha live prices and USDA carcass prices showed a high correlation (P<.0001; r=.98; Figure 1). The price spread for the 6-year period between Omaha live and USDA carcass prices ranged from $14.02 in January, 1989 to $23.18 cwt in November, 1990. The average spread was $17.53. The difference between live and carcass prices represents the amount the packer is paid for services. The spread has changed only marginally over the past 6 years, with carcass prices following the same seasonal pattern as live price. The maximum price received generally occurs during June and July, and the minimum price at the end of the year.

Average weekly live prices in 1992 for Omaha and St. Joseph also were highly correlated (P<.0001; r=.99). The mean price spread between Omaha and St. Joseph live prices was $0.66 cwt. Weekly Omaha prices ranged from $37.23 to $49.85 cwt, and St. Joseph prices ranged from $36.88 to $49.00 cwt. The standard deviations for Omaha and St. Joseph were $3.04 and $2.98 cwt, respectively.

The average 1992 weekly Omaha live and USDA carcass prices were highly correlated (P<.0001; r=.97). The price spread for the 1992 weekly Omaha live and USDA carcass prices ranged from $14.47 to 18.61 cwt, with an average of $16.17 cwt.

Seasonality of Wholesale Cut Prices. Previous research at Kansas State University in 1993 indicated that loin and ham cuts were important determinants of carcass value. Loins and hams represented 40% of the carcass weight and 60% of the carcass value.

Seasonal trends in live hog, carcass, loin, and ham prices are depicted in Figure 2. Loin prices were highly correlated (P<.0001; r=.85) with carcass prices. Loin prices followed a similar seasonal pattern as carcass and live prices, except loin prices declined to a greater degree in October and November.

Ham prices were also correlated (P<.0001; r=.65) with carcass prices. However, the seasonal pattern for ham prices differed from that of loin prices. Ham prices did not increase as rapidly during the summer months and strengthened during the holiday buying season of Thanksgiving and Christmas. This increased support of ham prices in the fall tends to offset the seasonal weakness in loin prices.

The seasonality of spare ribs and Boston butts is shown in Figure 3. The enormous demand for spareribs during the summer outdoor cooking season is evident with the maximum seasonal price occurring during May, June, and July. Spare rib prices were correlated (P<.0001; r=.51) with carcass prices, but to a lesser degree than the other wholesale cuts. Boston butt price was highly correlated (P<.0001;

r=.88) with carcass price. The seasonal prices for butts follow a similar pattern to that of live hog and carcass prices. The seasonal price patterns for bellies, trim, and jowls also followed that pattern.

Table 1. Granger Causality Tests for Weekly Wholesale and Farm Pork Prices, 1987-1992

Farm Market	Null Hypothesis	Weekly Lags	F-Statistics[a]
Omaha:			
	Wholesale causes farm	4	1.947
	Farm causes wholesale	3	35.948*
St. Joseph:			
	Wholesale causes farm	5	3.981*
	Farm causes wholesale	3	24.461*

[a] An asterisk indicates statistical significance at P<.05.

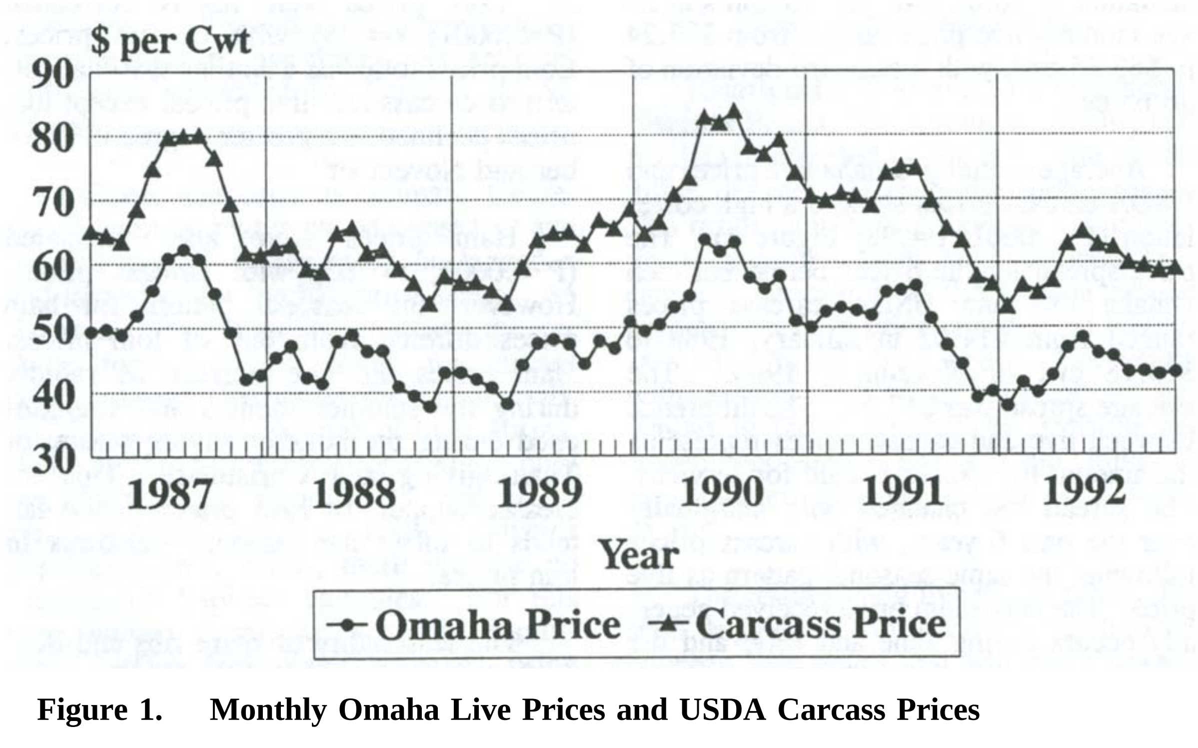

Figure 1. Monthly Omaha Live Prices and USDA Carcass Prices

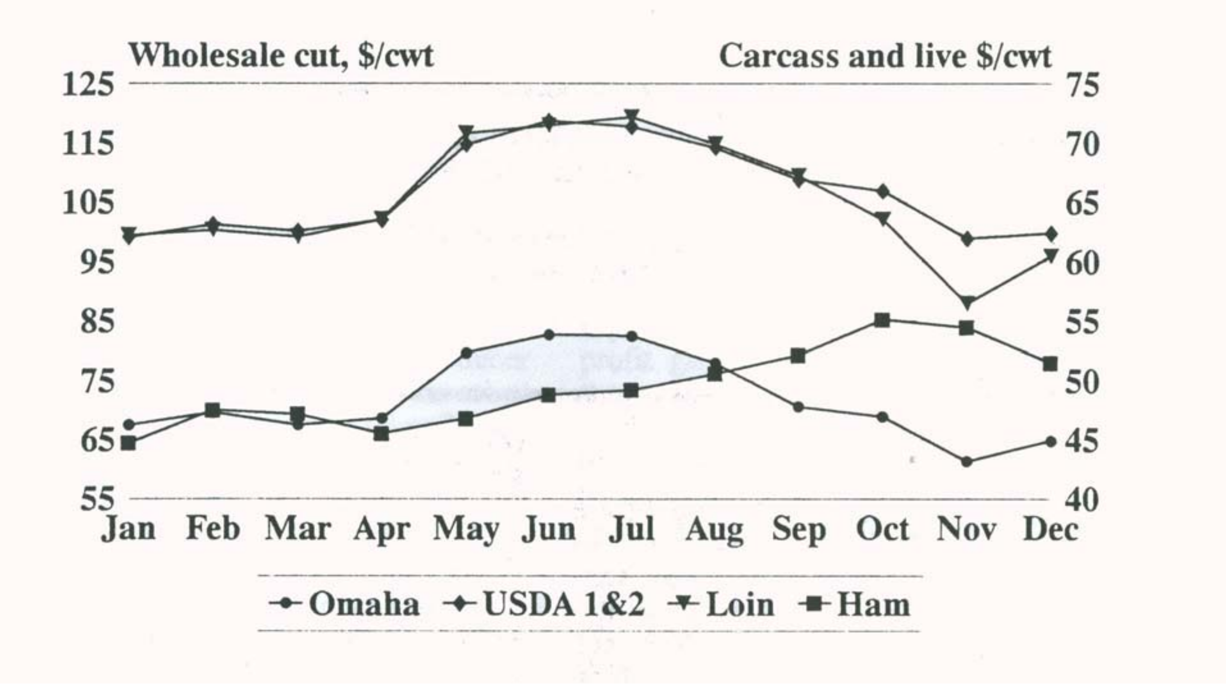

Figure 2. **Seasonal Trends in Live Hog, Carcass, Loin, and Ham Prices**

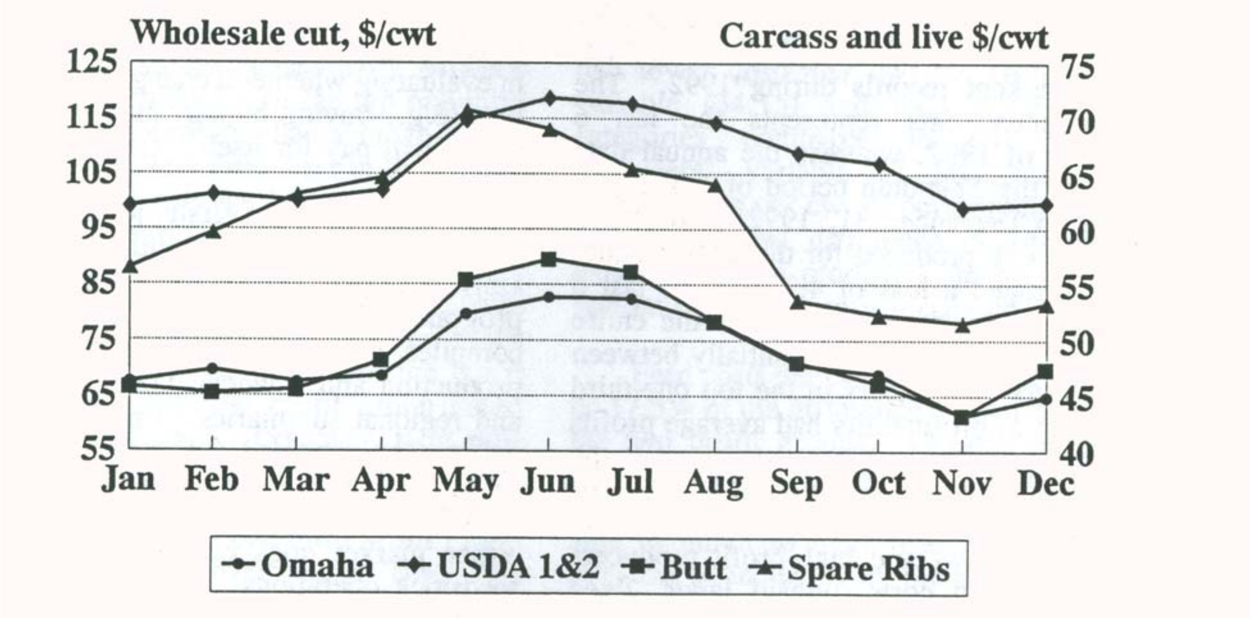

Figure 3. **Seasonal Trends in Live Hog, Carcass, Butt, and Spare Ribs Prices**

KANSAS STATE UNIVERSITY SWINE ENTERPRISE RECORD SUMMARY[1]

B. T. Richert, R. D. Goodband, M. L. Langemeier[2], M. D. Tokach, and J. L. Nelssen

Summary

Approximately 30 swine operations are enrolled in the 1992 - 93 Kansas Swine Enterprise Record Program provided by Kansas State University. This program evaluates biological and economic performance and is part of a cooperative record-keeping project with extension personnel and swine producers in Kansas, Nebraska, and South Dakota. Records are summarized every 6 months, and the corresponding data are pooled to form state and regional averages.

This summary is the combined data for the 18 farrow-to-finish operations in Kansas that kept records during 1992. The semi-annual data represents the last 6 months of 1992, whereas the annual data are for the 12-month period of January 1, 1992 to December 31, 1992. Profit per cwt of pork produced for these 18 producers averaged a loss of 4.78 for the last 6 months and a loss of $.52 for the entire year. Profits varied substantially between producers. Producers in the top one-third in terms of profitability had average profits of $5.72 per cwt, whereas producers in the bottom one-third had average losses of $6.97 per cwt for the year. Critical factors separating low- and high-profit producers included feed costs, unpaid labor, fixed costs, and sow productivity.

(Key Words: Enterprise, Records, Analysis, Profitability.)

Introduction

Production and financial records have become essential management tools of many swine producers. Production records measure the productivity of an operation. Financial records measure economic performance. An accurate set of records allows producers to compare their efficiency levels with those of other producers and to track performance over time. Records are particularly useful when making capital purchases of buildings and equipment and in evaluating whether a change in an operation (e.g., buying higher quality breeding stock) will pay for itself.

Kansas State University joined the University of Nebraska and South Dakota State University in a cooperative record-keeping program in January of 1991. This program compiles individual producer records on production and financial factors into state and regional summaries. Enterprise summaries are provided for farrow-to-finish, feeder pig producing, feeder pig finishing, combination (less than 70% of pigs sold as either market hogs or feeder pigs), and seedstock operations. Many of the items are recorded on the basis of per cwt of pork produced. Recording costs on a per cwt

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[1] The authors wish to thank Mike Brumm and Dale Kabes, University of Nebraska, for their assistance with the program and the many Kansas County Extension Agricultural Agents for their assistance.

[2] Dept. of Agricultural Economics.

basis facilitates comparisons between producers of various sizes.

Kansas Group Summary

Individual producers collect data on hog inventories, hog sales, hog purchases, feed inventories, feed purchases, operating expenses, labor, fixed expenses, and herd performance. These individual producer data were used by extension personnel at Kansas State University to compile the 1992 Kansas groups summaries reported in Table 1. Profit per cwt of pork produced on an economic life depreciation basis (Line 20) is used to separate producers into top and bottom one-third profit groups. Thus, all other items represent the means for that particular profit group. The information in Table 1 allows producers to compare the performance of their operation to that of other producers in the program.

Profit per cwt of pork produced for the 18 farrow-to-finish producers in the program averaged slightly below breakeven (-$.52 per cwt) over the whole year. However, profits varied substantially between producers. Producers in the top one-third in terms of profitability had average profits per cwt of $5.72. Producers in the bottom one-third had average losses of $6.97 per cwt for the year.

Notice that returns over cash costs (Line 2) were positive for all three profit groups for the whole year. For the last 6 months, only the low profit group could not cover cash costs. Typically, most producers can cover cash costs, even when prices are relatively low. However, producers in the bottom one-third profit group were not able to cover unpaid labor and fixed costs for the last 6 months and the year. The average producer also could not cover these costs in the last 6 months of 1992; thus, their return to management was negative (line 3). These producers will need to cover unpaid labor and fixed costs to stay in business in the long-run. The need to develop some management options that will improve their profitability in the future is indicated.

Line 4 presents the annual rate of return on capital invested in the swine operation. This rate should be compared to the rates that can be earned on other investments (e.g., banks, stocks). The return on capital for producers in the high one-third profit group was substantially more than the average return on capital for all 18 producers for the entire year. Note that the return on capital for producers in the bottom one-third profitability group was negative (-6.57) for the entire year.

Variable costs per cwt (Line 10) can be broken down into four categories: feed costs (Line 5), other operating expenses (Line 6), interest costs on operating capital (Line 9), and unpaid labor and management (Line 38). Total costs per cwt include these variable costs, plus interest charges on investments in buildings and equipment (Line 12) and economic life depreciation, taxes, and insurance costs (Line 13). Producers in the top one-third profit group had lower costs per cwt for each of the variable (34.15) and total (37.50) cost categories compared to the average producers' variable (37.90) and total (43.57) costs per cwt of pork produced. A $13.77 per cwt difference in total costs existed between producers in the top and bottom one-third profit groups for 1992.

Feed costs per cwt accounted for $2.41 or 17.5% of the difference in total costs for the two profit groups. Cheaper diets do not correspond directly to lower feed costs. However, the top one-third producers were able to purchase their feed for less (line 52), and as indicated by the supplement to grain ratio, they may have been feeding higher quality diets. A 9.8% improvement in feed efficiency occurred between producers in the top vs bottom one-third profit groups for the last 6 months of 1992; however for the whole year, the improvement in feed efficiency was only 4.5%.

Other operating expenses include utilities, hired labor, supplies, repairs, veterinarian costs, and professional dues. Other operating expenses and interest costs on capital accounted for 20.1% and 2.8% of the difference in total costs between producers in the high- and low-profit groups.

More efficient use of available labor can be a key difference in producer profitability. Unpaid labor and management were $2.43 per cwt higher for producers in the low-profit group than for producers in the high-profit group for 1992. This difference in unpaid labor and management accounted for 20.4% of the difference in total costs per cwt between the two groups.

Differences in fixed costs per cwt accounted for the remaining 41% of the difference in total costs between producers in the high- and low-profit groups for the year. Producers in the top one-third group had more litters per sow per year (line 25), weaned more pigs/litter (line 28), had more pigs produced per crate (line 30), and had lower finishing pig death loss (line 33). However, the number of pigs sold per litter farrowed (line 31) was similar between the top and bottom one-third profit groups. This probably reflects pigs held back or marketed shortly after the record period was closed out by the top one-third producers. Producers in the bottom one-third group had relatively more capital invested in facilities on a per cwt of pork produced basis (10.99 vs 34.40). This indicates that lower profit producers may have newer facilities or may need to improve their throughput with the facilities to spread with the fixed costs out over more pigs produced.

An interesting component to compare is average price received per cwt of pork produced. Generally, a wide range of prices is received because of the different marketing strategies used by producers in the state. However, regardless of profitability group, a comparison of individual state enterprise records summaries indicates that producers in Kansas receive approximately $.50 to $.75 less per cwt than producers in Nebraska and $1.00 less per cwt than producers in Iowa.

Finally, swine enterprise records serve as a useful management tool for individual producers to monitor their individual herd's production and economic performance over the last 6 months and for the year. As swine production becomes more competitive, the identification of good or problem areas of an operation becomes increasingly essential for producers to maintain profitability. By comparing an individual's records to the group summary, key economic criteria can be identified and management strategies implemented to improve profitability. The KSU Swine Enterprise Record program is an integral part of the swine extension service offered by Kansas State University.

Table 1. Kansas Group Summary Averages for Farrow-to-Finish Operations

	Farrow to Finish Operations					
	Semi-Annual Data (18 farms)			Annual Data (18 Farms)		
	Average	High 1/3	Low 1/3	Average	High 1/3	Low 1/3
1. Net pork produced, lbs.	209,576	337,512	180,002	458,496	658,510	309,176
2. Income over feed, oper. exp., oper. int., & hired labor	12,689	35,135	(5,606)	40,215	65,510	25,555
3. Profit or return to management, ELD	(5,455)	12,246	(25,196)	388	29,545	(21,782)
4. Annual rate of return on capital, ELD	-3.30	13.74	-21.77	7.33	24.99	-6.57
Variable Expenses:						
5. Total feed expense/cwt pork produced	24.41	23.15	27.47	24.39	23.50	25.91
6. Other oper. expenses (total)/cwt pork produced	7.09	5.44	10.57	6.79	5.09	7.86
a. Utilities; fuel, electricity, phone/cwt pork produced	1.55	1.13	1.92	1.32	1.13	1.66
b. Vet. expenses and medications/cwt pork produced	1.02	.68	1.39	.99	.71	.85
c. Remainder of other oper. expenses/cwt pork produced	4.52	3.63	7.26	4.48	3.26	5.34
7. Total cost of labor/cwt of pork produce	5.92	4.69	7.15	5.86	4.58	7.39
8. Total oper. capital inv./cwt of pork produced	20.51	18.60	24.29	17.65	16.10	19.34
9. Int. cost on oper. invest./cwt of pork produced	2.46	2.23	2.92	2.12	1.93	2.32
10. Total variable cost/cwt of pork produced	38.63	34.49	45.39	37.90	34.15	42.14
Fixed and Total Costs:						
11. Total fixed cap. inv. (ELD)/cwt of pork produced	22.35	11.91	28.58	21.47	10.99	34.40
12. Int. chg. on fixed inv. (ELD)/cwt of pork produced	2.24	1.19	2.86	2.15	1.10	3.44
13. E.L. deprec., taxes and ins. cost/cwt of pork produced	3.59	2.27	4.59	3.53	2.25	5.69
14. Tax deprec., taxes and ins. cost/cwt of pork produced	2.24	1.34	3.05	2.42	1.12	4.32
15. Fixed cost (ELD)/female/period	99.02	63.42	123.55	200.02	129.52	321.75
16. Fixed cost (ELD)/crate/period	475.44	321.40	633.22	983.30	562.09	1635.80
17. Total cost (ELD)/cwt of pork produced	44.46	37.95	52.84	43.57	37.50	51.27
18. Total cost (ELD)/female/period	765.32	708.20	879.81	1556.93	1475.70	1789.66
19. Total cost (ELD)/crate/period	3689.40	3608.96	4392.74	7608.16	6741.15	8961.34
Income and Profit						
20. Profit based on Econ. Life Deprec./cwt of pork produced	-4.78	2.91	-14.14	-.52	5.72	-6.97
21. Profit based on Tax Deprec./cwt of pork produced	-3.60	3.10	-12.95	.57	6.88	-5.31
22. Profit based on Econ. Life Deprec./female/period	-71.45	71.84	-234.12	-9.79	226.89	-243.87
23. Profit based on Econ. Life Deprec./crate/period	-378.01	279.83	-1188.27	-139.58	942.46	-1244.92

Semi-Annual Date July 1, 1992 - December 31, 1992 & Annual Date January 1, 1992 - December 31, 1992
Profit, fixed and total costs are based on Econ. Life Deprec. unless stated otherwise.

Table 1. (cont'd)

	Semi-Annual Data (18 farms)			**Annual Data** (18 Farms)		
Production summary:	Average	High 1/3	Low 1/3	Average	High 1/3	Low 1/3
24. Average female inventory	117	177	106	123	154	87
25. Number of litters weaned/female/period	.86	.96	.83	1.75	1.99	1.67
26. Number of litters weaned/crate/period	4.09	4.84	4.06	8.42	9.04	8.25
27. Number of live pigs born/litter farrowed	9.87	10.09	10.15	10.10	10.09	10.07
28. Number of pigs weaned/litter farrowed	8.15	8.69	8.37	8.46	8.44	8.13
29. Number of pigs weaned/female/period	7.26	8.26	6.89	15.06	17.19	14.06
30. Number of pigs weaned/crate/period	34.71	41.66	34.01	72.82	77.94	70.22
31. Number of pigs sold/litter/period	8.33	8.20	8.85	8.06	7.79	8.04
Death Loss:						
32. Birth to weaning (% of no. born)	14.26	15.86	15.96	14.45	15.60	15.55
33. Weaning to market (% of no. weaned)	6.56	6.70	6.14	5.91	5.29	6.85
34. Breeding stock (% of breeding herd maintained)	1.99	2.15	2.58	4.53	4.07	6.32
Labor:						
35. Labor hours/cwt of pork produced	.80	.65	.95	.80	.61	1.04
36. Labor hours/female/period	13.37	11.54	15.52	28.03	23.17	35.70
37. Labor hours/litter weaned/period	15.87	12.62	18.84	16.32	11.81	21.45
38. Cost of unpaid labor & mgmt./cwt of pork produced	4.67	3.66	4.44	4.60	3.63	6.06
39. Total cost of labor (paid + unpaid)/cwt of pork produced	5.92	4.69	7.15	5.86	4.58	7.39
40. Total cost of labor (paid + unpaid)/female/period	99.85	84.64	117.07	207.12	177.18	254.71
41. Return/hour for all hours of labor and management	2.70	13.65	-8.58	8.39	18.32	-.059
Marketing and Purchases:						
42. Number of market hogs sold	826	1285	744	1751	2594	1159
43. Average weight/head for market hogs sold	242	244	240	242	242	245
44. Average price received for market hogs/cwt	42.52	42.66	42.84	42.03	42.24	41.44
45. Number of feeder pigs sold	3	7	0	11	18	16
46. Average weight/head of feeder pigs sold	131.8	146.8	0	91.8	112.9	66.5
47. Average price received/head for feeder pigs sold	78.49	74.68	0	56.43	50.04	68.93
48. Average price received/cwt for feeder pigs sold	82.21	60.22	0	69.68	43.26	90.52
Feed Cost and Consumption:						
49. Total lbs of feed fed/cwt of pork produced	396	378	415	378	380	397
50. Total lbs of grain fed/cwt of pork produced	315	297	331	300	298	320
51. Total lbs of supplement fed/cwt of pork produced	80	81	84	78	82	77
52. Average costs of diets/cwt	6.17	6.11	6.62	6.48	6.20	6.57

Semi-Annual Date July 1, 1992 - December 31, 1992 & Annual Date January 1, 1992 - December 31, 1992
Profit, fixed and total costs are based on Econ. Life Deprec. unless stated otherwise.

ECONOMIES OF SIZE FOR FARROW-TO-FINISH HOG PRODUCTION IN KANSAS

M. R. Langemeier[1] and T. C. Schroeder[1]

Summary

Economies of size measure the impact on average cost of production of increasing the size of operation. Data from 91 farrow-to-finish operations enrolled in the Kansas Farm Management Associations in 1992 were used to empirically estimate economies of size. Results indicate that average total cost and operation size are significantly correlated, and that average total cost declines as operations become larger. Results also indicate a substantial variability in costs of production between producers. In fact, costs of production between producers of a given size vary more than costs of production between operations of different sizes.

(Key Words: Economies of Size, Cost of Production, Profitability.)

Introduction

Economies of size measure the relationship between the size of operations and the average cost of production. Economies-of-size measures are useful in answering questions such as:

What is the most profitable farm size?
Do larger farms have a lower break-even price?
Will the number of farms continue to decline?

If average total costs decline rapidly as the size of the farm increases, we would expect the industry to become more consolidated. Conversely, if average total costs are similar for farms of different sizes, the incentive would not be as strong for the industry to consolidate.

The number of operations with hogs declined by 63% from 1980 to 1992. This trend implies that it was economical for hog producers to become larger over this 13-year period. Economies-of-size measures can be used to determine whether it would be advantageous for farms to become larger. The purposes of this study were to examine economies of size for farrow-to-finish production in Kansas and to analyze differences in cost of production between producers.

Procedures

Enterprise data from 91 farrow-to-finish producers enrolled in the Kansas Farm Management Associations in 1992 were used in this study. Enterprise data included the size of the operation in litters, cwt produced, gross income, costs of production, and pigs weaned per litter.

A cost function was estimated by regressing size variables on average total cost per cwt. If economies of size exist, the size variables in this regression would be significantly different from zero.

This study also used data from the Kansas Farm Management Associations to separate producers into top and bottom one-

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third profit groups. Return above total cost was used to separate the 91 producers into profit groups.

Results and Discussion

Figure 1 presents the fitted average total cost function for the 91 farrow-to-finish operations. The scatter points in Figure 1 represent average total cost per cwt for individual farms. Size was significantly correlated with average total cost per cwt. Average total cost per cwt does not reach a minimum for the size range depicted in Figure 1. The fitted cost curve reaches a minimum at 830 litters. However, because only a few farms in the sample had more than 650 litters, it is not possible to draw inferences with respect to average total costs for this size category.

Using the fitted average total cost curve in Figure 1, we can compare break-even prices between farms of various sizes. Average total cost for a farm with 200 litters is about 4% lower than average total cost for a farm with 100 litters. Average total costs for firms with 400 and 600 litters are about 10% and 13% lower than average total cost for a firm with 100 litters. Cost advantages on a per cwt basis for larger farms include lower operator labor costs, lower depreciation and interest on buildings and equipment, and lower feed costs.

As indicated by the scatter points in Figure 1, a tremendous amount of variability exists in total costs between operations. In fact, differences in cost of production between farms of the same size are much wider than differences in costs of production between large and small firms.

Table 1 presents financial and production factors for the average farm compared to those in the bottom and top one-third in terms of return over total cost. The average size of the farms in the top one-third profit group is about 80 litters larger than the average size of the farms in the bottom one-third group. However, the top one-third profit group contains farms of all sizes. Variable costs includes hired labor, repairs, interest paid, feed, veterinarian expenses, utilities, fuel, and miscellaneous cash costs. Fixed costs include operator labor, depreciation and interest on buildings and equipment, and real estate taxes.

Sale price for producers in the top one-third profit group was $0.95 per cwt higher than sale price for producers in the bottom one-third profit group. Producers in the top one-third group either do a better job of marketing their hogs or have higher quality hogs.

The gross margin ratio is a measure of economic efficiency. Gross margin is calculated by dividing variable cost per cwt by gross income per cwt. A lower ratio indicates that a firm is more efficient. The gross margin ratio for producers in the top one-third profit group is significantly lower than that for producers in the bottom one-third profit group.

Costs of production on a per cwt basis are significantly lower for producers in the top one-third profit group. A large proportion (50%) of the difference in cost of production between profit groups can be attributed to differences in feed costs. We do not have feed conversion data on these farms. However, other studies have indicated that farms in the top one-third group have lower feed conversions and are more efficient in terms of purchasing feed ingredients. Another 26% of the difference in costs of production can be attributed to fixed costs. The remaining 24% of the difference in costs of production results from differences in variable costs other than feed.

Cwt produced and pigs weaned per litter are substantially higher for farms in the top one-third profit group. Gross income per cwt and higher productivity help explain the large difference in gross income per litter between producers in the top and bottom one-third profit groups.

Table 1. Selected Financial and Production Factors for Farrow-to-Finish Hog Producers in Kansas

Item	Bottom One-third (30 farms)	Average (91 farms)	Top One-third (30 farms)
Financial Factors ($ per cwt)			
Gross income	40.35	41.35	42.44
Sale price	41.37	41.78	42.32
Feed cost	29.81	26.00	22.83
Variable cost	39.90	34.18	29.51
Total cost	48.64	40.80	34.62
Gross margin	0.99	0.83	0.70
Financial Factors ($ per litter)			
Gross income	712.62	784.23	870.90
Feed cost	520.79	487.17	465.89
Variable cost	697.66	640.30	603.75
Total cost	851.92	763.51	709.27
Return above variable cost	14.97	143.93	267.16
Return above total cost	-139.31	20.72	161.63
Production Factors			
Number of litters	172	222	254
Number of pigs sold	1336	1717	2034
Sale weight (lb)	238	239	240
Cwt produced per litter	17.21	19.01	20.59
Pigs weaned per litter	7.12	7.45	7.82

Source: Kansas Farm Management Associations (1992).

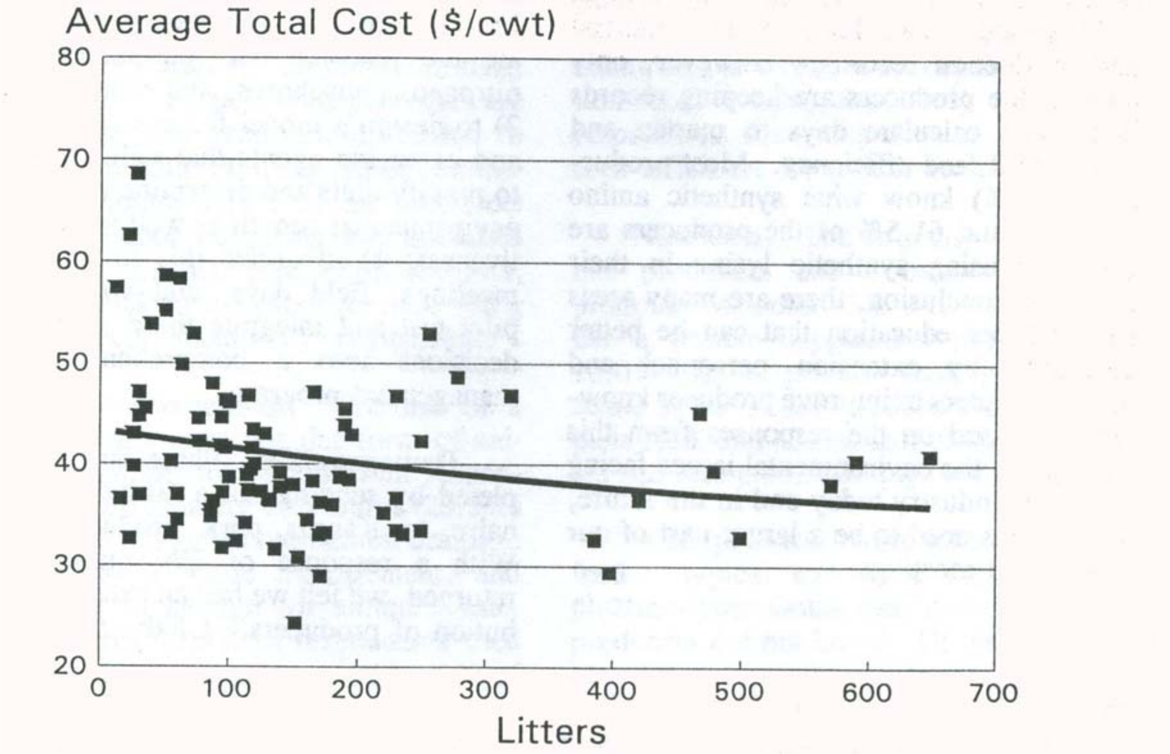

Figure 1. Total Cost per cwt for Farrow-to-Finish Hog Production in Kansas, 1992

INTEGRATED SWINE SYSTEMS "THE ANIMAL COMPONENT " - PHASE ONE; THE KANSAS STATE UNIVERSITY SURVEY

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Summary

A total of 650 questionnaires were sent to Kansas swine producers, and 279 were returned. There was an excellent distribution in producer size based on number of pigs marketed per year and producer age and educational level. The use of a lagoon to store swine waste is the most popular method in Kansas (38.8% of the respondents). One-third of the swine waste is disposed of by surface spreading and only 10.0% is applied primarily by soil injection. Less than one-half (45.5%) of the producers feel that nitrates in swine waste are environmental concerns and even less (27.0%) are concerned about phosphorus environmentally. Two-thirds of Kansas swine producers are keeping both financial and production records. However, only 44% of the producers are keeping records that could calculate days to market and whole-herd feed efficiency. Most producers (85.1%) know what synthetic amino acids are and 61.5% of the producers are currently using synthetic lysine in their diets. In conclusion, there are many areas for producer education that can be better addressed by extension personnel and industry leaders to improve producer knowledge. Based on the responses from this survey and the environmental issues facing the swine industry today and in the future, these issues need to be a larger part of our educational meetings.

Introduction

The public sector is becoming increasingly interested in the impact of animal agriculture on the environment. Kansas State University is taking a proactive stance in addressing these concerns. As part of a long-term commitment to protecting the environment, Kansas State University is currently engaged in a four-part project evaluate animal agriculture's impact on the environment and how this can be best managed.

The four components of this effort are as follows: 1) to determine producers current practices and knowledge pertaining to waste management and diet formulation; 2) to use on-farm demonstrations to evaluate the potential for minimizing excess nitrogen, phosphorus, and other minerals; 3) to design a model for use by producers and extension agents that will allow them to modify diets and determine the potential environmental benefit as well as cost effectiveness; 4) to utilize this information at meetings, field days, and workshops to pilot test and integrate these management decisions into a comprehensive swine management program.

Demographics. Phase one was completed by sending out a 60-item questionnaire to Kansas pork producers (650). With a response of 279 questionnaires returned, we felt we had an excellent distribution of producers. Of the respondents, 35.1%

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[1] The authors would like to extend a sincere thank you to the many swine producers that completed the survey.

market 1,000 or fewer pigs/year, 26.5% market 1,000 to 2,000 pigs/year, 15.8% market 2,000 to 5,000 pigs/year, 11.8% market 5,000 to 10,000 pigs/year, and 10.8% market more than 10,000 pigs/year.

Most producers had farrow to finish operations (75.5%). Finishing pig (10.1%) and feeder pig production (8.3%) make up smaller segments of the Kansas pork production. Combination operations that have less than 70% of their production as feeder pig or finishing make up another 6.1% of the Kansas pork production.

Based on producer age, Kansas is experiencing similar percentages of producers entering the industry (13.3% under the age of 30) and possibly preparing to leave (12.2% over 61 years of age). The majority (61.2%) of our producers are between the ages of 31 and 50. Most of our producers (95%) have completed high school. Over two-fifths (42.3%) of our producers have continued their education to receive a four year college degree. Of the remaining producers, 18.7% have a vocational degree or 2 years of college.

Even with Kansas' moderate climate, only 8.0% of the state's pork producers are using all outdoor facilities, compared to 32.7% of producers using total confinement. Although 40.4% of the producers are using indoor farrowing and nurseries with the rest of their production outdoors, another 18.9% of the producers are using some other combination of confinement.

Waste Management. The use of a lagoon was the most popular form of animal waste storage for 38.8% of the respondents. Approximately one-fourth (25.2%) of the swine producers use natural drainage or dirt lots in waste management, and 18.3% use pit storage for animal waste. The remaining 17.7% of respondents used a storage tank (4%) or a combination of these four storage methods.

Only 10.0% of the producers use injection of manure as the primary waste disposal method, whereas 33.7% use surface spreading as the main method of waste disposal. Another 15.4% use the lagoon oxidation-breakdown system, with 16.1% of the respondents using dirt lots. The remaining 24.8% of Kansas swine producers use a combination of these disposal methods or diversion terraces. Over one-fifth (21.9%) of the producers still feel that manure has no economic value as fertilizer.

When asked how much swine waste one pig will generate by the time it is marketed at 250 lb, many producers (73.7%) answered uncertain, whereas almost one-fifth (19.1%) answered the question correctly at 1.5 tons.

Records. Almost all (98.9%) Kansas producers are using some form of records; however, 6.5% of the respondents are not keeping production or financial records. Almost two-thirds (62.5%) of the producers are keeping records that are both financial and production oriented. Another 21.7% of the records kept are strictly financial, and only 9.4% are mainly production records. In answer to a question attempting to measure the depth of production records being kept, only 44% of the respondents could cite days to market and feed efficiency from their records.

Nutrition. The majority (43.2%) of our producers use a base-mix feeding program. Another 31.6% of the producers use a protein supplement program, and 16.0% use a premix feeding program. Also, 9.1% of the producers buy a complete feed, and almost half of these producers sell less than 1000 pigs per year.

When producers were asked how much feed a typical sow herd finishing 18.5 pigs/sow/year would eat, one-third of the producers did not know. Of the producers that did answer the question, 46.5% answered correctly at 7.25 tons/sow/year, with an even percentage missing on either side of this answer.

Most producers know what synthetic amino acids are (85.1%), and 61.5% of producers are currently using synthetic lysine in their diets. The concept of "ideal" protein is starting to gain identification with producers, as was evident by 61.3% of the producers correctly identifying its definition and purpose.

However, two newer ideas that are not well understood by producers are chelated minerals and phytase. Almost one-half (49.2%) of the producers were uncertain what a chelated mineral is. A chelated mineral is one that is complexed to a carrier to increase the mineral's absorption. Phytase, which is not yet available in the United States, was missed by 85.7% of the respondents. Phytase is an enzyme that will release phosphorous from its bound state (as found in plant products) to make it available to the animal for absorption. These products will increase in importance as pressure is applied to reduce nutrient excretion from the farm.

A large share (77.6%) of the producers correctly identified the gilt as having a higher protein requirement. However, 80.1% of our producers still do not split-sex feed. Over one-half (58.1%) of the respondents that do not split-sex feed feel they do not have enough pigs to justify doing it. Another one-third (32.5%) of the producers that are not split-sex feeding gave physical limitations in their facilities (number of feed lines etc.) as the main reason.

Environment. As environmental regulations require livestock producers to improve their waste management, it is essential to understand the producer's feelings on the potential environment hazard their swine waste may pose. Less than one-half (45.6%) of the pork producers feel that the nitrate in swine waste is an environmental concern and even fewer (27.0%) are concerned about phosphorus. This lack of concern is backed by 84.7% of the producers not testing their swine waste at all. However, 10.6% of producers do test animal waste for nitrogen and phosphorus to achieve correct land application rates.

Copper may also be a mineral with future environmental concerns. Over one-half of the (58.7%) producers expressed an environmental concern about copper. Interestingly, this is a higher percentage than was concerned about nitrates or phosphorus. Over one-half of the respondents correctly identified copper sulfate's primary use and function as a growth promotant/antimicrobial. Surprisingly, 32.4% of the producers reported that they don't use copper sulfate at all, and another 16.4% were not certain if it was in their diets or not. Almost one-third (31.3%) of the producers do use high levels of copper sulfate only in their nursery diets, whereas the remaining 19.9% use high levels of copper sulfate in some combination of nursery, grower, finisher, and sow diets.

Production and Management. When considering all producers, 53.4% responded that their days to market were between 175 and 190. Another 31.2% of the producers reported their days to market as less than 175 days. These percentages are very similar to producers that had kept both production and financial records. However, compared to those that kept only production records, 16% of these producers reported their days to market as under 175, and 60% reported their days to market as between 175 and 190 days. Actual days to market in the United States averages about 210 days. Approximately 40% of the finishing hogs marketed were between 230 and 240 lb, and another 41% were marketed between 240 and 250 lb. Similarly, 49.1% of the producers reported whole herd feed efficiencies between 3.0 and 3.5, and another 42.5% reported their herd feed efficiencies between 3.5 and 4.0.

One area of emphasis at Kansas State University over the past 10 years has been grinding swine diets to the proper particle size to improve feed efficiency, nutrient digestibility, and mixing efficiency. Almost one-half (44.5%) of the producers correctly identified the optimal particle size for swine performance at 700 microns, although 40.3% were uncertain of the correct particle size. However, 56.8% of Kansas pork producers have never submitted a diet sample for particle size testing.

Close to two-thirds of the Kansas pork producers are using a 1/8" hammer mill screen (29.1%) or a 3/16" hammer mill screen (30.0%). Another 19.8% of the producers are using a roller mill to process their grain. Hammers are replaced or rollers regrooved on 56.4% of the farms on an annual basis. Other important concerns for on-farm mixing are mixing efficiency and the time needed to achieve a good mix. Surprisingly, two-thirds (67.4%) of our producers have never conducted a mixing efficiency test of their own farm mixer.

Feeder Management. Over one-half (52.4%) of the feeders used by producers are less than 5 years old, and another one-third are between 5 and 10 years old. Most of these feeders are dry self-feeders (89.9%), with wet self-feeders making up another 7.5%. As feeders age, adjustment becomes more difficult. Most producers (65.3%) identified a feeder as properly adjusted when the pan is one-fourth to one-half covered. This feeder adjustment is checked once a day by 15.3% of the producers, once a week by 42.1%, and once a month by 22.6% of the producers. When feed is observed on the ground outside the feeder, most producers (64.7%) correctly answered that 10% or more feed wastage is occurring, but another 22.9% felt it was closer to 5% feed wastage. This 10% wastage would cost a typical farrow-to-finish producer with 100 sows approximately $10,000 per year, as was correctly answered by 59.6% of the survey respondents.

Weaning Management. As nursery diets have grown in complexity and pig performance postweaning has improved, few Kansas producers are weaning under 20 days of age (6.7%) and utilizing this technology. Approximately one-third of our producers are weaning pigs between 21 and 25 days of age and another one-third are weaning between 26 and 34 days of age. A large percentage, 23.2%, are still weaning over 35 days of age. Most producers (44.3%) are using two diets in the nursery after weaning. Another 29.8% are using three diet phases for piglets up to 50 lbs. However, many producers (51.5%) do not know the percent lysine in their initial postweaning diet. Of the producers knowing their first diet's lysine content, responses were; 1.2 (35.9% of the producers), 1.4 (24.7% of the producers), or above 1.4% (27.4% of the producers) lysine.

Finishing Management. American consumers are demanding wholesome, healthy pork as part of their diet. To help ensure this, the National Pork Producers Council has started the quality assurance program to reduce the incidence of drug residues in pork. Almost half (49.6%) of our producers are not taking advantage of this educational program. However, on the positive side, 16.5% of the producers are at Level II certification and 26.7% are at the highest certification on Level III. Most producers are feeding two (43.0%) or three (43.0%) diets from 50 lbs to market. These hogs are marketed in a variety of ways. The most common sale route is for producers to sell to a plant buying station (43.4%). The second most popular marketing avenue is to sell directly to the packing plant (31%). The majority (57%) of Kansas hogs are still sold on a live basis.

Sow Management. Most producers feed separate gestation and lactation diets (83.9%). These diets are typically 14% CP in gestation (51.6% of respondents) and 16% CP in lactation (40.9% of respondents). Sow feed intake during lactation will often vary from farm to farm because of environment, parity, and genetics. This was evident by the wide range of responses we received on sow feed intake during lactation. Approximately one-fourth of the respondents said their sows eat 10 lb per day and another one-fourth answered over 14 lb per day, but the largest share of producers (45.6%) said that their sows eat 12 lb per day.

Diet Additives. Most producers (79.0%) are adding antibiotics to their diets for disease control or enhanced pig performance. One-third of the producers are feeding probiotics in their diets. A small percentage (6.5%) of the producers are trying enzymes to enhance nutrient digestibility of their diets. A similar percentage (8.4%) are adding pit additives to their manure storage.

Information. The popular press is by far the largest single contributor to producer information, with 21.5% of the producers claiming magazines as their primary source of information. Extension personnel, feed companies, and veterinarians shared similar percentages at 11.3, 12.1, and 10.6% of the respondents primary source of information, respectively. Professional consultants made up another 7.9% of the primary information sources. The remaining 36.6% said that some combination of these sources shared equally in providing information.

In conclusion, pork producers' lack of concern for swine waste as an environmental issue indicates our lack of emphasis as industry leaders on environmental issues in the past and the need for more producer education in the future. Understanding current producer practices in herd management helps us improve the direction of agendas for producer meetings. This survey indicates some important areas that the pork industry needs to focus on to maintain our viability in animal agriculture.

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