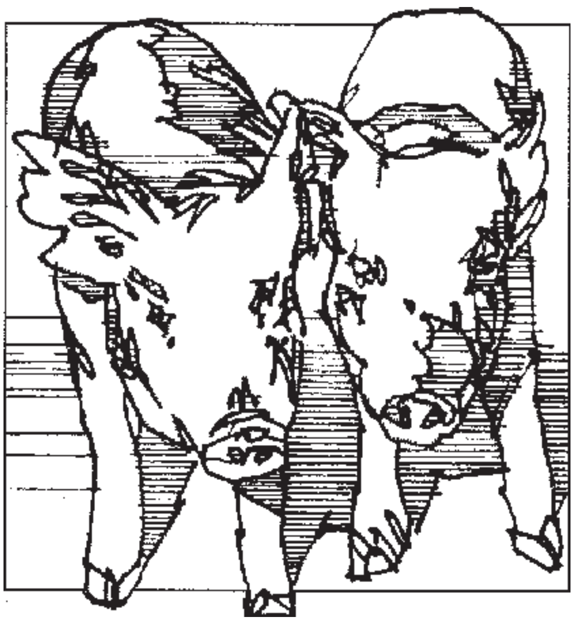

KANSAS
STATE
UNIVERSITY

SWINE DAY 1991

REPORT OF PROGRESS 641, AGRICULTURAL EXPERIMENT STATION, MARC A. JOHNSON, DIRECTOR

FOREWORD

It is with great pleasure that we present to you the 1991 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 meats, and physiology to nutrition. We hope that the information will be of benefit, as we attempt to meet the needs of the Kansas swine industry.

Editors, 1991 Swine Day Report,

Bob Goodband   Mike Tokach

ABBREVIATIONS USED IN THIS REPORT

avg	=	average	h	=	hour(s)	mo	=	month(s)
BW	=	body weight	in.	=	inch(es)		=	microgram(s)
cm	=	centimeter(s)	IU	=	international unit(s)		=	.001 mg
CP	=	crude protein				N	=	nitrogen
cwt	=	100 lb	kg	=	kilogram(s)	ng	=	nanogram(s)
d	=	day(s)	Kcal	=	kilocalorie(s)		=	.001
DM	=	dry matter	lb	=	pound(s)	no.	=	number
	=	Fahrenheit	Mcal	=	megacalorie(s)	ppm	=	parts per million
ft	=	foot(feet)	mEq	=	milliequivalent(s)	sec	=	second(s)
ft^2	=	square foot(feet)	min	=	minute(s)	wk	=	week(s)
g	=	gram(s)	mg	=	milligram(s)	wt	=	weight(s)
gal	=	gallon(s)	ml	=	cc (cubic centimeters)	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 10% Mn, 10% Fe, 10% Zn, 4% Ca, 1% Cu, .4% K, .3% I, .2% Na, and .1% Co.

Vitamin premix: each lb of premix contains vitamin A, 1,000,000 IU; vitamin D_3, 100,000 IU; vitamin E, 4,000 IU; menadione, 400 mg; riboflavin, 1,000 mg; pantothenic acid, 2,500 mg; niacin, 5,500 mg; choline, 100,000 g; and vitamin B_{12}, 5 mg.

Selenium premix: each lb of premix contains 272.4 mg Se.

NOTICE

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

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

CONTENTS

Growing Finishing Management

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.

HEALTH CONSIDERATIONS FOR THE YEAR 2000

Joseph F. Connor, D.V.M.[1]

As the swine industry matures, profit margins will decrease. Control of the major factors affecting feed cost will drive the system. Upgrading or maintaining health will be a major emphasis, because disease agents and complexes affect growing-finishing performance.

Many diseases, such as pneumonia caused by *Actinobacillus* (*Haemophilus*) *pleuropneumonia* and swine dysentery, dramatically affect growing-finishing performance. Diseases decrease average daily feed intake (ADFI) and increase feed per gain ratio (F/G) in many instances. At the same time, they increase input costs via treatments, vaccines, and feed additives. Historically, our control methods may have been successful on individual farms, but not across large populations. Because of the dynamics of disease complexes, it has been difficult to understand the disease agents and/or their interactions, let alone define a cost-effective method of control or elimination. However, several new techniques offer hope of optimizing the genetic capability of growing-finishing pigs with respect to average daily gain (ADG) and F/G. These control measures become more important as restrictions increase on therapeutic feed additives, injectables, and the producer's goal of providing a pork product untainted by residues of any kind. Likewise, in the future, available carcass-enhancing products, such as Ractopamine, may not allow simultaneous use of therapeutics, requiring production systems with pigs of high health status.

The ultimate goal of the production system for the year 2000 has the following components:

1. All in/all out pig flow;
2. All in/all out pig flow by sex;
3. Single stage production;
4. Close-outs on ADFI, F/G, mortality, and profitability by group;
5. Control or avoidance of respiratory and enteric disease complexes without massive individual or group animal treatment;
6. Less use of therapeutic antibiotics;
7. Residue avoidance;
8. More pounds of pork produced with less labor.

The tools developing to meet these goals by the year 2000 involve:

1. Biogenetics;
2. Vaccines;
3. Therapeutics;
4. Depopulation/repopulation;
5. Multiple-site production;
6. Modified, medicated, early weaning.

Biogenetics may produce a pig that is genetically resistant to various disease agents. However, the likelihood of this technology keeping up with the disease agents seems impossible and/or costly.

New, slow-release vaccines or therapeutics may be developed. Delivery systems may include implants or aerosol chambers. The time and cost of development may be an overriding factor.

Depopulation/repopulation continues to offer an excellent method of improving health of growing-finishing pigs. However, the length of the effect and the commitment to repeated depopulations need to be established. Practicality of re-

[1]Carthage Veterinary Clinic, Carthage, IL.

peated depopulations/repopulations must be evaluated on cost effectiveness, especially in a herd with good maternal production. Start-up effects, such as low farrowing rates, must be amortized over the whole repopulation effect.

Multiple-site production and modified, medicated, early weaning may allow us to fulfill the components for health by the year 2000. Multiple site establishes production phases with the hope that the break in people and pig contact will reduce disease transmission and provide the flexibility of eliminating or minimizing diseases that are in the nursery-through-finisher population. This type of production is used routinely in the poultry industry and has been used by some breeding companies in establishing new units to reduce health risks. In the near future, multiple sites will mean growing-finishing buildings with only one week's production of one sex of animals. Disease control, then, is designed around a separate facility system.

A progression of multiple-site production as diseases are established in the sow herd is modified, medicated, early weaning (MMEW), or Isowean™, which is a method to upgrade health status in nursery through finisher.

Modified, medicated, early weaning is a nonsurgical method for procuring minimal disease pigs. MMEW pigs can be free of numerous infectious agents such as *Mycoplasma hyopneumoniae*, *Actinobacillus pleuropneumoniae*, *Haemophilus parasuis*, *Streptococcus suis*, *Treponema hyodysenteriae*, *Pasteurella multocida*, *Bordetella bronchiseptica*, *Leptospira* species and diseases such as transmissible gastroenteritis and pseudorabies. These herds can also be free of external and internal parasites such as *Sarcoptes*, *Haematopinus suis*, *Ascaris suis*, *Trichuris*, and *Oesophagostomum*. As a result, these herds usually have greatly improved ADG and F/G in the growing-finishing phase.

The methods for deriving MMEW pigs are well described in literature and also have been detailed in past presentations made by Dr. Tom Alexander and Dr. Hank Harris. This procedure has been further developed by the Pig Improvement Company, Inc. in its Isowean Technology™ concept. The concept was developed as an extension of research initiated by Cambridge University in England in 1979 on Medicated Early Weaning. Research indicated that MMEW pigs are free of the variety of agents outlined above which could be present in the source herds. In the original MMEW procedures, pregnant sows were removed from the source herd in late gestation, placed in isolated farrowing accommodations, and medicated. Piglets were weaned at 5 days of age, removed from the farrowing environment, and placed in an isolated nursery separate from the source herd. At 20 to 35 kg, piglets were removed from the MMEW nurseries to another isolated grow-out unit.

Recently, the procedures have been modified so that farrowing is done in the original herd, but pigs are weaned into a second site. This allows a break in the production system to minimize the effect of disease.

The best application of this technology will be in commercial production herds with excellent maternal production but low health status, which reduces the performance of the animals in the growing-finishing phase and, thus, makes the herd economically noncompetitive. Many swine units, because of obtaining or adding additional facilities over the last 3 years, already have multiple sites, of which one or more can be utilized as an isolated nursery/ growing-finishing unit. The medication and vaccination protocol should be designed to eliminate the diseases that are inherent to a particular herd and are increasing production costs significantly in the grower-finisher.

We have been involved with several herds utilizing MMEW successfully for weaning ages of between 10 and 21 days of age. Over 10,000 pigs have been weaned in this manner with less than .5% mortality. This technique has been used to repopulate one producer's own herd.

This is an exciting time in the swine industry. Health effects on growing-finishing performance have come to the forefront. Control measures will allow a maturing industry to optimize costs.

KSU SWINE ENTERPRISE RECORD PROGRAM

R. D. Goodband*[1]*, M.L. Langemeier*[2]*,
***and M.D. Tokach*[3]**

Summary

On January 1, 1991, a enterprise record program was implemented on 13 swine operations in Kansas. The program evaluates economic criteria in the areas of variable and fixed costs, labor, marketing, and production and is conducted in cooperation with extension specialists and swine producers in Kansas, Nebraska, and South Dakota. Every six months, producers' records are summarized, and the data are pooled to form state and regional averages. This data base is then divided into the top, middle and bottom third of producers based solely on profit per cwt. of pork produced. This summary allows producers to compare their individual records to those of other swine operations and identify strengths and weaknesses in their operation. In addition, it also identifies the criteria that may have the greatest impact on profitability. The Kansas Swine Enterprise Records Program is an opportunity for producers who have never kept records to evaluate the profitability of their operations. It also allows producers who keep detailed biological records of their operations an opportunity to assess their financial profitability. In either case, records can establish a baseline level of production and profit in order to make sound management decisions.

(Key Words: Enterprise, Records, Analysis, Profitability.)

Introduction

As the swine industry becomes more competitive, sound management decisions based on accurate records are essential to remain profitable. Many different types of record keeping programs are available to swine producers; however, the two main types of record programs are biological and financial. Biological records typically detail reproductive and growth performance to measure the output of a swine operation. Financial records provide an itemized account of the return and cost categories on a per unit basis and analyze the operation's economic performance.

Recently, Kansas State University joined the University of Nebraska and South Dakota State University in a cooperative record keeping project to evaluate financial records of swine operations.

The Swine Enterprise Records Program is a relatively simple, do-it-yourself, hand-kept records program that assists producers in keeping production cost and return information. The program costs $60 per year and involves two training meetings (December and February) and two close-out sessions, where data are collected and summarized. At these close-out meetings, a producer gets a copy of his operation's records and then a copy is sent to Nebraska where group averages are compiled and summarized. State and regional averages for the top, middle, and bottom third of producers

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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 following county agricultural extension agents for their cooperation: Cathy Bandyk, Charles Call, Tim Eggleston, Art Johnson, Garry Keeler, David Key, Ed LeValley, Greg McClure, Frank Shoemaker, Joe Smith, and Ted Wary.

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based on profitability of cwt. of pork produced are then distributed. Because many of the items are based on cwt. of pork produced, the program is size neutral (i.e., efficiency of production rather than quantity is measured). Swine 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 purebred or SPF operations. This paper summarizes the records of the first 11 farrow-to-finish operations in Kansas that have completed the program. In addition, an example of how records may be used to make decisions is discussed.

Kansas Group Summaries

In the Swine Enterprise Records Program, data are collected on hog inventories, hog sales, hog purchases, feed inventories, feed purchases, operating expenses, labor, fixed expenses, and herd performance. Using these data, individual and group summaries are prepared (Table 1). Profit per cwt. on an economic life depreciation basis (Line 20) is used to separate producers into top and bottom one-third groups. Thus, all other items represent the means for that particular profit group. The resulting information gives producers a comparative analysis of their operations and helps identify key criteria that have the greatest impact on profitability.

Profit per cwt. on an economic life depreciation (ELD) basis is computed by dividing the return to management (Line 3) by the net pounds of pork produced (Line 1). The annual rate return on capital can be used to compare hog production to other investments. Hog production becomes an attractive investment when its rate of return to capital is high relative to other investments.

Variable expenses are broken down into feed (Line 5), other operating expenses (Line 6), and interest on operating expenses (Line 9). Variable costs per cwt. for the top one-third group were relatively lower than those for the bottom one-third group for every expense category. Of the various expenses, fed costs typically had the greatest impact on profitability. This is evident when total costs per cwt. are compared for the low and high one-third groups (Line 17). Of the $10.04 difference in total costs per cwt. between these two groups, $3.46 or 34.5% reflects the difference in feed costs per cwt. (Figure 1). Cheaper diets do not directly correspond to lower feed costs. The bottom one-third group of producers actually had less expensive diets (Line 52). The greater grain to supplement ratio fed by the bottom one-third group may indicate that a poorer quality diet was fed, which, in addition to other variables, may have created poorer feed efficiencies.

Other operating expenses and fixed costs also had an important impact on profitability. Other operating expenses include utilities, hired labor, supplies, repairs, veterinary costs, and professional dues. The difference in operating expenses between the top and bottom one-third groups is $2.63 per cwt. In percentage terms, other operating expenses are over 50% higher for the bottom one-third group.

Fixed costs include depreciation, interest charges on buildings and equipment, property taxes, and insurance. Fixed costs for the bottom one-third are about $3.00 higher per cwt. than those for the top one-third.

Income and profits are presented on a tax and an ELD basis. Economic life depreciation attempts to measure the actual annual decline in the value for the useful life of buildings and equipment. Economic life depreciation and tax depreciation are not equivalent. Tax depreciation is typically larger than ELD in the early years of an asset's life. Returns above cash costs are quite often positive. However, to stay in business in the long-run, producers will also need to cover unpaid labor, wear and tear on facilities, and the opportunity costs (Line 12) associated with owning facilities. Opportunity costs reflect the fact that the capital used to produce hogs could be used for other investments.

In the production summary, the average operation had 112 sows (Line 24). The number of live pigs born (Line 27), number of pigs weaned (Line 28), and preweaning mortality (Line 32) appear to be major factors influencing profitability. These factors contribute to pig throughput and also affect the number of pigs weaned per crate and sold per litter. The differences in these values between the top and bottom one-third of producers indicates that producers need to keep facilities full to enhance profitability.

There is a $1.18 difference in market price between the top and bottom one-third of producers for the average market price. This wide range is unique in that most other state's enterprise records typically indicate little difference in market price. The difference reported in our summary may reflect a greater diversity in marketing strategies between producers, given the lack of no major packing plants in Kansas.

There is a 16% difference in feed efficiency between top and bottom producers. This has a great impact on feed costs, because the bottom 1/3 of producers actually have less expensive diets. Again, this reflects that inexpensive feed is not directly correlated to profitability, but that feed cost per unit of pork produced is a more critical factor.

Using Records to Make Decisions

The primary goal of keeping enterprise records is to document the effect of management changes on profitability. In addition, enterprise records allow comparison of an individual's operation to means of those in the state or region. This can allow a producer to identify problem areas and to focus on one or two of these and try to improve them. An example of how this can be accomplished is provided in examining the records of a 200-sow producer (Table 2). In examining this producer's records, almost all criteria are above average, and many are in the top one-third of all producers. Based on these data, the producer is doing an excellent job and is making $6.74 per cwt. of pork sold. However, in comparing this producer's records to the state averages, it is easy to identify that he has a high total feed expense per cwt. of pork produced, resulting primarily from high diet costs. From this information, the producer's current feeding program and prices can be evaluated, and possible options can reviewed. Expected tonnage for each of the diets fed and their expected yearly costs were then calculated and compared to alternative diet formulations with ingredient options available to the producer. All alternative diet options used the same grain price and were formulated to meet or exceed those nutrient recommendations in the Kansas State University Swine Nutrition Guide. Thus, differences in prices did not reflect poorer quality diets, but rather "best cost" ingredients and a lower added fat level in the new options. To then determine the effect of the new diet options on profitability, a new output was formulated to reflect the change in feed costs, if the producer had switched to the alternative diet options but kept all other inputs fixed. However, because the new diets did not contain any added fat, feed efficiency would be expected to become poorer with the change to the new diets. Therefore, the new enterprise record summary also includes adjustments for greater feed usage to reflect approximately 5% poorer feed conversion (384 vs 403 lb of feed per cwt. of pork produced). As observed in the producer's new records summary, feed costs per cwt. of pork produced is reduced ($27.20 vs $22.18 per cwt.), even taking into account the poorer feed conversion. This results in almost doubling the profit per cwt. of pork produced ($6.26 vs $11.59 per cwt.).

These data provide the producer information necessary to evaluate other non-feed costs associated with a possible change in feeding program as well. For instance, new bulk bins or a new portable grinder mixer may need to be purchased. In addition, the producer may need to evaluate and implement a stringent quality control program for feed manufacturing. These inputs will need to be weighed against the possible returns the alternative feeding program. However, with the use of records, the costs and returns of involved with management decisions can be documented.

In summary, Swine Enterprise Records Program can be a useful management tool to help identify the strengths and weaknesses of an operation. As swine production becomes more competitive, records can be used to evaluate possible management strategies to lower the cost of pork production and increase profitability.

Table 1. Kansas Group Summary Averages (Farrow to Finish Operations)[a]

Item	Average[b]	Top 1/3	Bottom 1/3
1. Net pork produced, lb	187,341	202,424	116,627
2. Income over feed, oper. exp., oper. int., & hired labor	27,120	42,236	7,227
3. Profit or return to management, ELD	8,569	21,259	(5,935)
4. Annual rate of return on capital, ELD	16.92	38.16	-3.06
Variable Expenses:			
5. Total feed expense/cwt. pork produced	26.32	24.60	28.06
6. Other oper. expenses (total)/cwt. pork produced	7.35	4.98	7.61
a. Utilities; fuel, electricity, phone/cwt. pork prod.	1.74	1.40	1.50
b. Vet. expenses and medications/cwt. pork prod.	1.01	.92	.78
c. Remainder of other oper. expenses/cwt. prod.	4.50	2.66	5.33
7. Total cost of labor/cwt. of pork produced	7.15	6.31	7.41
8. Total oper. capital inv./cwt. of pork produced	22.98	20.23	24.70
9. Int. cost on oper. invest./cwt. pork produced	2.76	2.43	2.96
10. Total variable cost/cwt. of pork produced	42.25	37.96	44.95
Fixed and Total Costs:			
11. Total fixed cap. inv. (ELD)/cwt. pork produced	21.59	16.10	30.89
12. Int. chg. on fixed inv., (ELD)/cwt. pork produced	2.16	1.61	3.09
13. E.L. deprec., taxes and ins. cost/cwt. pork prod.	2.90	2.31	3.89
14. Tax deprec., taxes and ins. cost/cwt. pork prod.	2.19	2.00	2.72
15. Fixed cost (ELD)/female/period	80.85	68.97	106.17
16. Fixed cost (ELD)/crate/period	443.24	441.76	496.20
17. Total cost (ELD)/cwt. or pork produced	47.31	41.89	51.93
18. Total cost (ELD)/female/period	777.19	750.32	800.97
19. Total cost (ELD)/crate/period	4207.37	4416.52	3856.72
Income and Profit:			
20. Profit based on ELD/cwt. pork prod.	3.52	11.46	-5.07
21. Profit based on Tax Depreciation/cwt. pork prod.	4.26	12.10	-4.33
22. Profit based on ELD/female/period	70.79	212.48	-70.70
23. Profit based on ELD/crate/period	376.29	1029.08	-335.06

Table 1. CONT. Kansas Group Summary Averages (Farrow to Finish Operations[a])

	Average[b]	Top 1/3	Bottom 1/3
Production Summary:			
24. Average female inventory	112	118	73
25. Number of litters weaned/female/period	0.86	.86	.78
26. Number of litters weaned/crate/period	4.56	4.91	3.68
27. Number of live pigs born/litter farrowed	10.25	10.77	10.00
28. Number of pigs weaned/litter farrowed	8.01	9.10	7.08
29. Number of pigs weaned/female/period	7.17	7.91	6.25
30. Number of pigs weaned/crate/period	39.15	45.63	29.85
31. Number of pigs sold/litter farrowed	6.54	7.83	5.44
Death Loss:			
32. Birth to weaning (% of no. born)	15.14	16.28	28.64
33. Weaning to market (% of no. weaned)	4.98	4.07	7.18
34. Breeding stock (% of breeding herd maintained)	2.37	1.30	3.07
Labor:			
35. Labor hours/cwt. of pork produced	.97	.86	1.02
36. Labor hours/female/period	15.86	15.37	15.35
37. Labor hours/litter weaned/period	18.39	18.00	19.38
38. Cost of unpaid labor & mgmt./cwt. pork produced	5.82	5.96	6.31
39. Total cost of labor (paid + unpaid)/cwt. pork prod.	7.15	6.31	7.41
40. Total cost of labor (paid + unpaid)/female/period	116.76	111.90	111.84
41. Return/hour for all hours of labor and management	12.93	23.49	3.26
Marketing and Purchases:			
42. Number of market hogs sold	660	735	403
43. Average weight/head for market hogs sold	241	242	243
44. Average price received for market hogs/cwt.	51.90	52.38	51.20
45. Number of feeder pigs sold	61	0	67
46. Average weight/head of feeder pigs sold	50.6	0.0	50.9
47. Average price received/head for feeder pigs sold	35.50	0.00	30.90
48. Average price received/cwt. for feeder pigs sold	67.84	0.00	53.57
Feed Cost and Consumption:			
49. Total pounds of feed fed/cwt. of pork produced	393	365	425
50. Total pounds of grain fed/cwt. of pork produced	317	290	351
51. Total pounds of supplement fed/cwt. of pork prod.	76	75	75
52. Average costs of diets/cwt.	6.71	6.72	6.61

[a]Summary of 11 farms; January 1 through July 30, 1991.
[b]Average, top, and bottom one-third groups are determined by profitability per cwt. of pork produced (Line 20).

Table 2. Individual Swine Enterprise Records Analysis [a]

Item Costs	Actual Records	Kansas Summary Average	Adjusted for New Diet
Profit or return to management ELD	18,109	8,569	33,525
Total feed expense/cwt. pork produced	27.20	26.32	22.18
Total variable cost/cwt. pork produced	41.46	42.25	42.25
Total cost (ELD)/cwt. of pork produced	47.45	47.31	36.14
Profit based on Economic Life Depreciation/cwt. prk. prod.	6.26	3.52	11.59
No. live pigs born/litter farrowed	10.04	10.25	10.04
No. pigs weaned/litter farrowed	9.70	8.01	9.70
No. pigs weaned/crate/period	65.95	39.15	65.95
Avg. price received for market hogs/cwt.	52.12	51.90	52.12
Total lb feed fed/cwt. pork prod	384	393	403
Total lb grain fed/cwt. prk prod.	314	317	330
Total lb supplement fed/cwt. prk prod.	70	76	73
Avg. costs of diets/cwt.	7.08	6.71	5.50

[a]Swine Enterprise Records for a 200- sow, farrow to finish operation. Actual records are compared to the summary averages for 11 farms in northeast Kansas. Adjusted records reflect alternative diet costs and poorer feed conversion.

Figure 1. Percentage Difference in Production Costs Between Top and Bottom One-third of Producers Based on Profitability (Cost Difference of $10.04).

USE OF AGRONOMIC CONDITIONS, GENETICS, AND PROCESSING TO IMPROVE UTILIZATION OF SORGHUM GRAIN [1]

J. D. Hancock and P. J. Bramel-Cox [2]

Summary

Sorghum grain is an extremely important crop to both farmers and livestock feeders in the High-Plains states (e.g., from Nebraska to Texas). Kansas leads the nation in sorghum production, and as should be expected, Kansas State University has a long history of research to improve the utilization and marketability of this versatile and hardy crop. This paper is a synopsis of current research at KSU and other universities concerning production and use of sorghum grain for feeding swine. Topics addressed include the relatively small loss in nutritional value (4 to 11%) as test weight decreases from 55 to 35 lb/bu compared to the extreme discounts experienced by farmers trying to market light grain. Also, an experiment to quantitate yield of utilizable nutrients from corn and sorghum was conducted to determine the relative merits of these grain sources when grown with different irrigation and N application strategies. Finally, sorghum parent lines have been identified with improved digestibility, and alternative milling procedures (e.g., fine-grinding and extrusion) have been identified that should greatly improve the competitiveness of sorghum grain as a feedstuff of choice for swine diets.

(Key Words: Sorghum Grain, Irrigation, N Application, Genotype, Process, GF, Starter.)

Introduction

For centuries, sorghums have been produced in Third-World countries for human consumption with selection based largely on ease of milling and aesthetic value. In contrast, plant breeders in developed countries have focused almost entirely on yield characteristics, including resistance to disease, drought and insects. Unfortunately, very little emphasis has been given to development of sorghums superior for their ultimate fate, that is, their utilization as nutrient sources for livestock and humans. This paper is a review of environmental factors, genotypic traits, and processing procedures that affect quality and availability of nutrients provided by sorghum grain. Attention is given to means that can be used to maximize the feeding value of sorghum grain, thus increasing its utility in swine feeding.

Discussion

Agronomic Conditions. It is important to recognize that considerable variability in nutrient content and quality does exist in sorghum grain. The same factors that are forcing a re-evaluation of corn production in many areas (e.g., frequent droughts, unpredictable length of growing season, limited water supply, low soil fertility, etc.) undoubtedly cause the majority of the variation in nutrient content and quality of sorghum grain produced in these areas. Researchers in Oklahoma sampled grain from 15 sorghum varieties grown in 2 consecutive years at five locations. Crude protein ranged from 10.9 to 16.5%, and lysine as a percentage of crude protein ranged from 1.9 to

[1]Much of the discussion in this article is taken from a book chapter written by the authors. For copies of the complete manuscript, write to: Dr. Joe D. Hancock, Room 246, Weber Hall, Dept. of Animal Sciences and Industry, KSU, Manhattan, KS 66506-0201.

[2]Department of Agronomy.

2.3%. In a similar experiment at KSU, 100 sorghums were grown at two locations, with and without irrigation at one location, and with low versus high N application at a second location. Crude protein content ranged from 6.7 to 14.3%, and in vitro protein digestibility (pepsin digest) ranged from 59.9 to 82.6%. The question then becomes, would those differences in nutrient content and in vitro digestibility be reflected in differences in growth performance of pigs consuming the grain? Secondly, what factors might be controlled and(or) manipulated to minimize those differences in nutritional value?

One commonly occurring factor affecting nutrient content and quality of sorghum grain that cannot be controlled is frost damage. An experiment designed to test the effects of early frost on the nutritional value of sorghum grain for growing-finishing pigs was reported by researchers at Texas Tech University. As test weight increased from 32 to 48 lb/bu, rate and efficiency of gain increased by 6 and 8%, respectively, but increasing test weight to 56 lb/bu did not further improve growth performance. Indeed, pigs fed the sorghum with intermediate test weight had numerically the greatest rates and efficiencies of gain. Similar results were reported by scientists at Kansas State University and South Dakota State University in 1990 and 1991. An early frost in the fall of 1989 resulted in sorghum with test weights from 30 to 60 lb/bu produced in the same one-county area near Garden City, KS. Sorghums with normal, intermediate, and light test weights (55, 45, and 35 lb/bu, respectively) were purchased from several producers and blended within test weight. As test weight decreased from normal to light, crude protein concentration of the sorghum grain increased from 9.7 to 11.5%. There was more than a 3-fold increase in percentage crude fiber as test weight decreased from normal to light. In growing and finishing pigs, the intermediate sorghum was equal to normal sorghum for rate and efficiency of gain. However, the blend of normal and light sorghums was of lower nutritional value than the intermediate sorghum, especially for finishing pigs. These results indicate that current recommendations of blending normal and light test weight sorghums to obtain optimum growth performance should be re-evaluated. Perhaps an even more important observation is that the reductions in feeding value of the light test weight sorghum (4% in chicks, 11% in growing pigs, 7% in finishing pigs, and equal feeding value in growing cattle) is not indicative of the severe penalties in price paid for those sorghums. However, this still leaves the question of what can be done to optimize the nutritional value of sorghum grain by manipulation of factors that can be controlled.

Experiments with well defined growing conditions for cereal grains produced at the same location are difficult to find. A limited number of such experiments have been reported with corn, indicating that both irrigation and N fertilization affect the yield and quality of nutrients in normal and high lysine corn. KSU researchers reported similar results for sorghums raised under varied agronomic conditions (Table 1). Treatments were corn, bronze pericarp hetero-yellow endosperm sorghum grain (BSG), and a yellow pericarp homozygous-yellow endosperm sorghum grain (YSG) grown with optimum or minimum irrigation, with or without N application. The grains were produced on a small scale and, thus, chick assays were used to model the probable responses in pigs. This project was targeted especially for the farmers/feeders who market their sorghum grain through their own swine operations. When averaged across irrigation and fertilization treatments (Experiment 1), G/F of chicks fed the corns was not different than G/F of chicks fed the sorghums. However, chicks fed the BSG had improved G/F compared to chicks fed YSG. The greater feeding value of BSG was confirmed in a separate experiment to determine ME_n of the grain treatments (Experiment 2), with lower ME_n for YSG than BSG. Evaluation of the grain treatments for protein quality, using a modified chick PER assay (Experiment 3), indicated that corn was not different than the sorghums and that the protein of YSG was of greater quality than the protein of BSG. Optimum irrigation increased yield by 44%, and N application increased yield by 9%. Yield of utilizable nutrients (yield × G/F), utilizable energy (yield × ME_n), and utilizable protein (CP yield × G/F) were affected more by irrigation than N application, with grain source having only a minimal effect. However, interactions between grain source, irrigation level, and N application indicated that water stress resulted in greater loss of utilizable nutrient yield for corn and YSG than BSG. Also, both sorghums yielded more utilizable nutrients than corn at comparable levels of added irrigation, because water applied was similar for the low-irrigation corn treatments and the optimum-irrigation sorghum treatments (i.e., total moisture from rain and irrigation was 37.4 in for optimum-corn, 28.0 in for low-corn, 31.5 in for optimum-sorghum, and 20.9 in for low-sorghum). These results favor use of sorghum to maximize nutrient yield in areas of limited rainfall and(or) a dwindling supply of water for irrigation. Comparing the sorghums produced without irrigation, the BSG had greater feeding value (G/F in Experiment 1), but the YSG had greater protein quality (G/F in Experiment 3). However, the greater yield of BSG resulted in greater yield of UN and UP compared to YSG. Thus, the current concerns about improved feeding value with yellow pericarp and(or) homozygous-yellow endosperm sorghums seems unfounded. Other genetic factors would seem to merit more attention than pericarp color and endosperm color.

Table 1. Effects of Agronomics on Yield of Utilizable Nutrients from Corn and Sorghums[ab]

	Corn				Bronze sorghum				Yellow sorghum			
	Irr		Low-Irr		Irr		Low-Irr		Irr		Low-Irr	
Item[c]	+N	-N	+N	-N	+N	-N	+N	-N	+N	-N	+N	-N
Exp. 1												
Yield, kg/ha	7601	7272	5687	5197	7937	6597	5790	5229	8427	7802	4827	4865
G/F	.710	.712	.716	.693	.723	.741	.725	.716	.668	.693	.705	.697
UN, kg/ha	5397	5178	4072	3602	5738	4888	4198	3744	5629	5407	3403	3391
Exp. 2												
GE yield, Gcal/ha	31.5	30.7	23.6	21.7	32.8	27.3	24.0	21.9	34.6	32.4	19.7	19.7
ME_n, kcal/kg	3593	3282	3137	3314	3699	3323	3187	3484	3315	3610	3111	2977
UE yield, Gcal/ha	27.3	23.9	17.8	17.2	29.4	21.9	18.5	18.2	27.9	28.2	15.0	15.5
Exp. 3												
CP yield, kg/ha	671	601	508	481	821	609	609	544	752	665	462	468
G/F	.645	.646	.651	.658	.635	.638	.607	.633	.661	.652	.647	.654
UP, kg/ha	433	388	331	317	521	389	370	344	497	434	299	306

[a]Adapted from Richert et al. (1991).
[b]Treatment abbreviations are Irr = irrigated, Low-Irr = minimum irrigation, +N = with N application, -N = without N application.
[c]Item abbreviations are UN = utilizable nutrients (G/F × yield), GE = gross energy, ME_n = metabolizable energy, UE = utilizable energy (ME_n × yield), UP = utilizable protein (G/F × protein yield).

Genotype. The nutritional value of various fairly simply inherited traits, such as pericarp color and endosperm color, type, and texture, have been investigated. Researchers in Arkansas reported that sorghums with yellow pericarp were better utilized by nursery pigs (fed from 10 to 20 kg body weight) than sorghums with brown pericarp, but the latter had high tannin content (i.e., .67% vs .22% for the brown and yellow sorghums, respectively). Simple correlation coefficients were -.68 and -.58 between tannin content and digestible energy and digestible protein, respectively. Thus, these experiments did not address the issue of differences in nutritional value between sorghums with different pericarp colors but similar tannin content. In a Nebraska experiment, sorghums with bronze, cream, and yellow pericarp colors were compared to corn for feeding nursery and growing-finishing pigs. Nursery pigs gained 5 to 8% slower with all sorghum types but with similar efficiency to pigs fed corn. In a growing-finishing experiment, pigs fed the sorghums gained 4% slower and were 4 to 9% less efficient than pigs fed corn. The authors concluded that reduced palatability of sorghums may be more of a problem in very young animals and reduced energy value more of a problem in older animals, but no consistent differences were due to pericarp color.

In contrast to pericarp color, differences in endosperm characteristics have been suggested to affect nutritional value. There are reports in ruminants of higher nutritional value for sorghums with yellow versus white endosperm color. However, it is most difficult to rationalize why digestive enzymes might prefer endosperm with yellow pigmentation. It's more probable that early experiments reporting differences among sorghums with different endosperm colors actually may have been comparisons of differences in endosperm type and texture.

Studies with ruminants and in vitro experiments indicate improved digestibility for waxy endosperm type and floury endosperm texture, but pig experiments at Texas A&M have shown no differences in dry matter, energy, or protein digestibility for waxy versus normal sorghums. Furthermore, comparison of sorghums with floury, intermediate, and corneous endosperm indicated that intermediate endosperm was superior to floury endosperm for both dry matter and energy digestibility. Sorghums with floury and corneous endosperm had similar digestibilities. Florida researchers compared sorghum grain with waxy and normal endosperm types and low, medium, and high tannin content fed to nursery pigs. As tannin content increased, rate and efficiency of gain decreased, but sorghum with waxy endosperm was no better nutritionally than sorghum with normal endosperm.

The lack of improvement in energy digestibility and utilization in swine fed floury and waxy endosperm sorghums and the realization that very soft or floury sorghums have reduced yield and poor weathering ability have stimulated research at KSU into the relationship of yield and digestibility. Direct selection was made in a sorghum population for improved in vitro protein digestibility (digestibility in pepsin) from 100 S_1 families, which were grown at five locations for 2 years. Growing conditions greatly influenced sorghum digestibility, and higher protein digestibility was associated with lower yield and later maturity. In view of these undesirable relationships, a selection index was developed to include the rank for yield plus the rank for digestibility minus the rank for bloom date, with selection restricted to families in the top 50% for yield and protein digestibility. Heritability for this index was 38%, and it identified 20 families with improved protein digestibility, better grain yield, and earlier maturity. From this population, two lines were selected with consistently low in vitro digestibility and two lines with consistently high in vitro digestibility. When these sorghums were fed to growing-finishing pigs that were fitted with ileal cannulas, digestibility of gross energy increased from 74% for the low digestibility sorghums to 77% for the high digestibility sorghums, compared to a digestibility of 80% for corn. In chick feeding assays, these lines, respectively, supported rates of gain that were 95, 96, 98, and 100% that of the corn control and efficiencies of gain that were 95, 97, 98, and 100% that of the corn control. Overall, the authors concluded that use of in vitro protein digestibility, in conjunction with yield and maturity date, has potential to genetically improve grain sorghum as a feed grain for livestock, even though the environment will still have a major effect on nutritional quality. Unlike selection for floury and waxy endosperm, this selection index would result in genetic material for use in hybrids with acceptable yield, maturity, and weathering ability and improved nutritional value for pigs.

Processing. Handling/processing techniques have included grinding, crushing, steaming, steam flaking, popping, and extruding. During the past 2 years, we have conducted experiments showing that extrusion processing of sorghum grain improved nutrient digestibility and efficiency of growth in finishing pigs (Figure 1). Texas A&M researchers reported a linear improvement in ileal and total tract energy digestibility in growing pigs as particle size of sorghum was reduced from approximately 1,300 to 600 µm by hammermilling. Researchers here at KSU reported similar findings, in that nitrogen and dry matter digestibilities and efficiency of gain for pigs fed corn and sorghum grain improved linearly as particle size was reduced from greater than 1,000 µm to below 700 µm. Thus, extrusion and reducing particle size did seem to improve the feeding value of sorghum grain for swine.

In a direct comparison of the effects of coarse grinding and fine grinding of different cereal grains (corn, yellow sorghum, and bronze sorghum), Nebraska researchers reported that fine grinding (600 vs 1200 µm) im-proved efficiency of gain in finishing pigs fed corn or yellow sorghum, and that dry matter and nitrogen digestibilities were improved more by fine grinding of the sorghums than for corn. Data from our laboratory indicate that power usage was two to four times greater to roller mill corn than hard and soft endosperm sorghum grain, at particle sizes ranging from 900 to 500 µm (Figure 2). When these grains were fed to weanling pigs (Figure 3), optimum F/G was at 300 µm for d 0 to 7 and 500 µm for d 0 to 35. When milled to their optimum particle sizes, feeding values of hard and soft sorghum grains were 105 and 93% that of corn from d 0 to 7 and 94% that of corn from d 0 to 35. From these data, we concluded that weanling pigs responded more to fine grinding (300 to 500 µm) early in the growth phase. Perhaps most important was showing that the sorghums could be milled to 500 µm with less energy cost and greater tonnage/h than required to mill corn to 900 µm. Thus, finely ground sorghum (300 to 500 µm) merits serious consideration as an alternative to corn in diets for early-weaned pigs (for 2 wk post-weaning). It should be noted that these results were from feeding pelleted diets, thus the problems reported with bridging and reduced flowability in diets with small particle size were not a concern. A complete report of this project can be found elsewhere in these proceedings (Healy et al.).

In conclusion, sorghum is an excellent feedstuff for swine. Although the feeding value of sorghum is on average 3 to 7% less than that of corn, cost of sorghum in many areas is commonly 10 to 15% less than the cost of corn. In addition to the current economic and environmental incentives for using sorghum, scientists are improving its feeding value through plant breeding, increased understanding of agronomic practices, and improved milling and processing procedures that will result in optimum nutritional value. With these advances and with the superior sustainability of sorghum production with minimal rainfall, the future of sorghum as a major feed grain for use by Kansas swine producers seems promising.

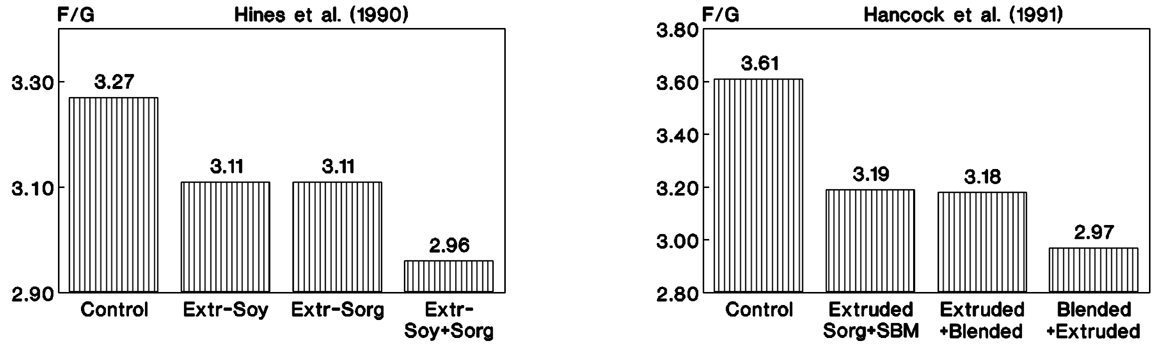
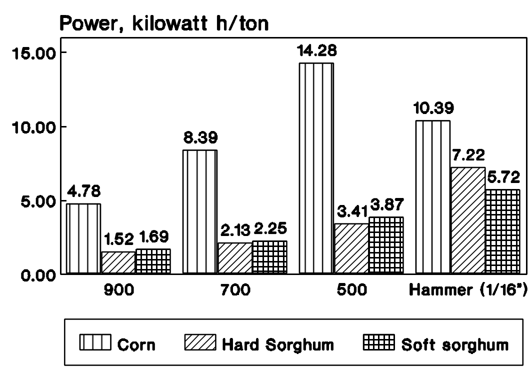


Figure 1. Replacing Ground Sorghum, Soybean Meal, and Soybean Oil with Extruded Sorghum, Extruded Soybean Meal, and Extruded Soybeans in Diets for Finishing Pigs. Treatments for Hines et al. were: Control = ground sorghum, soybean meal and soybean oil; Extr-Soy = ground sorghum and extruded soybeans; Extr-Sorg = extruded sorghum, soybean meal and soybean oil; Extr-Soy + Sorg = extruded sorghum and extruded soybeans. Treatments for Hancock et al. were: Control = ground sorghum, soybean meal and soybean oil; Extruded Sorg+SBM = sorghum, soybean meal and soybean oil blended and extruded; Extruded+Blended = extrusion of sorghum and soybeans before blending; Blended+Extruded = extrusion of sorghum and extruded soybeans after blending.

Figure 2. Energy Required to Roller Mill Corn is Two to Four Times Greater than that Needed to Roller Mill Sorghum to Particle Sizes from 900 to 500 Microns. The same trend was observed when fine-grinding (1/16" screen) in a hammermill. (Adapted from Healy et al., 1991.)



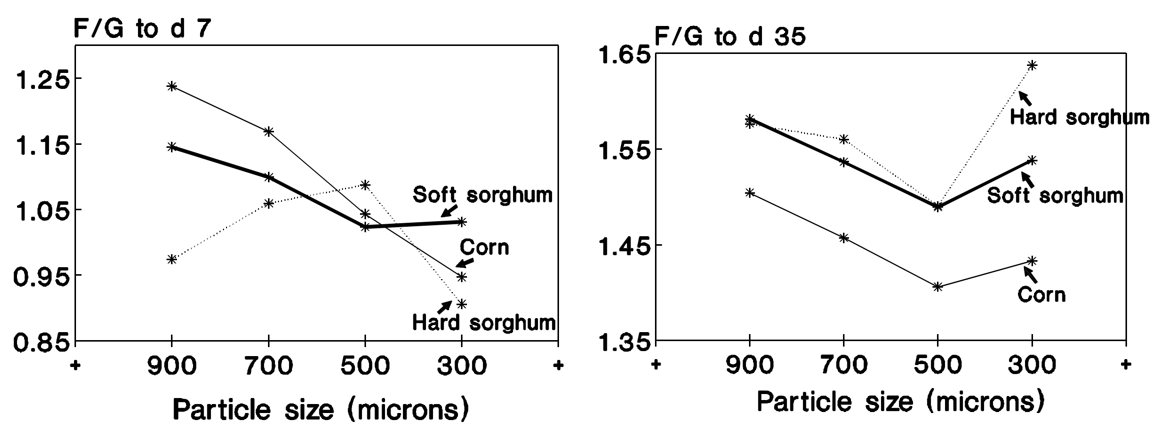


Figure 3. Optimum Particle Size of Cereal Grains Differs with Age of Weanling Pigs and Grain Source. (Adapted from Healy et al., 1991.)

KSU LEAN GAIN ASSESSMENT PROGRAM

M. D. Tokach[1,2], J. L. Nelssen,
R. D. Goodband, and G. L. Keeler

Summary

KSU Lean Gain Assessment is a new program developed at Kansas State University to allow producers to assess the actual lean gain of their pigs under normal farm conditions. The procedure is inexpensive and relatively simple and provides information that will assist producers in monitoring their genetic progress. Additionally, farm-specific diets can be formulated to match nutrient levels with the actual genetic potential of pigs on an individual farm[2].

(Key Words: Genetics, Nutrition, Lean Gain.)

Introduction

Consumer demand for lean, closely trimmed pork has increased steadily during the last 10 years. Packers are realizing the extra value of lean hogs that eliminate the need for excess fat trimming. Additionally, producers are understanding that producing hogs with excess fat is inefficient and expensive.

These facts have led to changes in the standard terminology of assessing pig performance and profitability. Daily gain, feed efficiency, and cost per pound of pork produced are being replaced by lean gain, lean tissue feed conversion rate, and cost per pound of lean pork produced. Lean gain is defined as gain in carcass lean divided by number of days on test. Lean tissue feed conversion is the ratio of pounds of feed consumed divided by pounds of carcass lean produced. Cost per pound of lean pork produced is simply total costs divided by total pounds of lean produced.

Nutritionists are stressing the importance of feeding hogs to their "lean gain potential." Feed companies are designing feeding programs for "high lean gain" or "medium lean gain" genetics. Unfortunately, lean gain is impossible to predict visually. Because producers have not had an effective means of assessing the lean growth potential of their hogs, these feeding programs and nutritional recommendations cannot be accurately employed or fully utilized.

Producers must also ask the question: "Do I have the genetic base to compete in a lean value system in the future?" To assist in answering this question, the KSU Lean Gain Assessment program was developed. The KSU Lean Gain Assessment program is an inexpensive, relatively simple method of assessing the lean gain of an individual producer's hogs under normal farm conditions.

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[2]Producers interested in this program should contact Mike Tokach (913-532-5833) or Gary Keeler (Douglas County Agent; 913-843-7058) for assistance in determining the most convenient means of data collection.

Reasons to Assess Lean Gain

1) It allows assessment of the genetic base of a swine herd to determine if a genetic change is warranted.

2) Farm-specific diets can be formulated to match nutrient levels to actual genetic potential of pigs.

3) It provides an accurate measure of genetic improvement. Lean gain can be re-assessed periodically to determine the improvement made in lean meat production in a specific swine operation.

4) It helps the producer determine market strategies.

Information Needed to Determine Lean Gain

1) **Pig Identity.** Pigs must be ear notched for week of birth or litter to allow tracking through the production system.

2) **Initial Weight.** Initial weight must be obtained between 40 and 70 lb. The objective is to obtain the age and average weight of all pigs, while they are in this weight range. Randomly weigh approximately 10% of the pigs in the nursery phase to obtain an accurate estimate. This weight can be taken as pigs leave the nursery or at a set time during the nursery phase. The critical criteria to record at this time are initial wt, date weighed and number of pigs with each ear notch represented in the group.

3) **Carcass Data.** Ear notches and date must be recorded when pigs are sold. The group of pigs for the lean gain assessment must be sold to a plant using the Fat-O-Meater™ probe. The closest plant using this probe is Farmland Foods at Crete, Nebraska. They have agreed to supply the Fat-O-Meater™ tapes with the needed carcass data. The carcass data include: hot carcass wt (lb), backfat depth (cm), and loin eye depth (cm).

Lean Gain Calculations

Lean gain/d can be determined using the following formulas.

$$\text{Lean gain/d} = \frac{\text{Carcass muscle - Initial muscle}}{\text{Days on test}}$$

a) Initial muscle = -3.5 + (.44 × initial wt)

b) Carcass muscle (lb) = 18.8 + (HCW × .44) + (LED × 2.11) - (BF × 7.7)

- Loin eye depth (LED) and back fat (BF) are measured in centimeters by the Fat-O-Meater™. Hot carcass weight (HCW) is measured in pounds.

c) Days on test = Days from initial wt to market.

Example: A group of pigs had the following data:

Initial wt = 40 lb   Days on test = 110 d

Carcass measurements:
HCW = 176 lb
BF = 2 cm LED = 6 cm

Initial muscle = -3.5 + (.44 × 40 lb) = 14.1

Carcass muscle = 18.8 + (176 lb × .44) + (6 cm × 2.11) - (7.7 cm × 2) = 93.5

$$\text{Lean gain/d} = \frac{93.5 - 14.1}{110} = .72 =$$

lean growth genotype

How to Use Lean Gain Results

Listed below are lean gain ranges to categorize hogs as a low, medium, or high lean gain genotype. After the genotype is categorized, management decisions can be made concerning genetics, nutrition, and marketing.

Lean gain/d		Genotype
< .6	=	Low
.6 to .75	=	Medium
> .75	=	High

Genetics. If results indicate that hogs have low or medium lean gain, the producer must decide whether to make a genetic change. Producers with pigs of a medium lean gain genotype may consider improved boar selection, whereas producers with pigs that have low lean gain may contemplate the need for repopulation with an improved genotype. Producers with pigs of a high lean gain genotype will be challenged to make further improvements.

Nutrition. Regardless of the outcome of the lean gain assessment, producers will be able to more accurately match their nutritional program to their genetic base. Producers with pigs with low or medium lean gain genotypes may want to decrease nutrient levels to the level of pig performance. Providing more protein or energy than the pig can use for protein deposition is expensive, will not improve performance, and may actually decrease daily gain. Thus, nutrient levels and diet costs can be decreased, while maintaining the same performance and carcass value.

If the test determines that genotypes are superior (high lean gain), nutrient levels can be increased to match nutrient intake with lean gain potential. Ultimately, profits will be increased by enhancing growth performance and return-above-base because of improved lean product for the packer. For the example listed above (.74 lb lean gain), the producer may want to increase protein level of the diet and reevaluate lean gain to assure that the protein content of the diet was not limiting lean growth. Producers should work with their nutritionist and/or extension specialist to determine the appropriate nutritional changes.

Marketing. If a producer has pigs with superior lean growth, they should be marketed to a packer that rewards lean meat production and discounts fat accretion. Conversely, if lean gain is below average, selling on a live basis may be advantageous to avoid discounts these pigs would receive on a grade and yield basis.

Costs of Program to the Producer

The only costs to the producer for this program are small increases in labor and limited marketing opportunity for the load of pigs being used to determine lean gain. Extra labor is needed to ear notch pigs at birth, obtain initial weight, and record ear notches at market. The limited market opportunity results from the need for the pigs to be sold to Farmland Foods to obtain Fat-O-Meater data. At least 50 pigs should complete this program to accurately assess lean gain. The accuracy of the assessment is directly related to the number of pigs completing the program.

ONE-DAY SUPPLEMENTATION WITH TYROSINE DID NOT AFFECT REPRODUCTIVE TRAITS OF SOWS[1]

I. Rettmer, R. D. Goodband,
J. S. Stevenson, and D. L. Davis

Summary

Primiparous and multiparous sows received a single dietary supplement of L-tyrosine in their feed on the day after weaning, and the effects on various reproductive traits were evaluated. Sows received either none (control; n = 21) or 45.5 mg L-tyrosine/lb BW (tyrosine; n = 22) on the day after weaning. In Exp. 1, days from weaning to estrus (5.1 ± 1 vs 5.3 ± .9 d) and ovulation rate (number of corpora lutea on ovaries on d 5 after estrus) (16.3 ± 4.4 vs 16.2 ± 4) were similar in control and tyrosine-supplemented sows. In Exp. 2, (control; n = 63; tyrosine; n = 53) days to estrus were extended by tyrosine supplementation (6.4 ± .5 d) compared to control sows (4.6 ± .5 d), but total numbers of piglets born (10.6 ± .4 vs 10.1 ± .4) were similar in control- and tyrosine-treated groups. Therefore, a single dietary supplementation with tyrosine on the day after weaning failed to influence interval to estrus, ovulation rate, or litter traits.

(Key Words: Tyrosine, Sows, Weaning, Estrus, Litter Size.)

Introduction

The amino acid L-tyrosine is the substrate for the synthesis of various catecholamines (e.g., dopamine, norepinephrine, epinephrine) in the brain. Uptake of L-tyrosine from the blood plasma across the blood-brain barrier depends on the concentration of L-tyrosine relative to the concentrations of the other members of the family of large neutral amino acids (i.e., tryptophan, phenylalanine, valine, leucine, and isoleucine), all of which compete for a common membrane-bound transport mechanism. Research has indicated that brain functions are modified by altering the supply of amino acids that serve as precursors for the synthesis of neurotransmitters.

A number of German studies have demonstrated profertility effects of a dietary supplementation with L-tyrosine in several species, when L-tyrosine was fed near the onset of estrus. According to recent work at the University of Minnesota, the concentrations of L-tyrosine in plasma of sows were lowest at the time of the first estrus following weaning. Therefore, our objective was to determine the effect of a single dietary supplement of L-tyrosine given the day after weaning on reproductive performance in sows.

Procedures

Two experiments involving primiparous and multiparous sows were conducted at two locations in Kansas. Sows received either none or 45.5 mg/lb BW of L-tyrosine (Lonza Inc., Fairlawn, NJ) as a single dose, mixed in their regular diet 24 h after litters were weaned. Detection of estrus and breeding were done by the respective herd personnel, and interval to estrus was defined as the time from weaning until the first observed standing estrus.

Experiment 1 was conducted at the Kansas State Swine Teaching and Research Unit with sows assigned randomly to receive L-tyrosine (tyrosine; n = 22) or to serve as non-supple-

[1]The authors thank Henry's LTD, Longford, KS, for asistance in data collection and use of animals and facilities in Exp. 2.

mented controls (control; n = 21). On d 5 after standing estrus, laparotomy was performed and number of corpora lutea were countd in a subset of sows.

Exp. 2 was conducted in cooperation with a Kansas swine producer. Crossbred sows were assigned randomly to treatments (ontrol; n = 61; tyrosine; n = 53). Data collected were interval to estrus, length of gestation, number of pigs born alive, mummified pigs, stillborn pigs, total number of pigs born, week of weaning, body condition score of the sows at weaning, and parity.

Results and Discussion

A summary of results from Exp. 1 is in Table 1. Average interval to estrus after weaning was unaffected by supplementation with tyrosine, and number of corpora lutea (ovulation rate) were similar in control and tyrosine-supplemented sows.

In Exp. 2, interval to estrus was 1.8 d longer (P<.01) in tyrosine-supplemented sows than in control sows, but subsequent litter traits of sows that conceived at the first postweaning estrus were similar (Table 2).

Under the circumstances of our experiments, L-tyrosine may not have been rate-limiting in the synthesis of catecholamines at the time of treatment. Swine diets in Germany are based on wheat and barley compared to corn and milo-based diets in the U.S. and that could explain the different results in our studies and those conducted in Germany.

In conclusion, supplementing sows with L-tyrosine on the day after weaning failed to shorten the interval from weaning to estrus or to increase ovulation rate and subsequent litter traits of sows.

Table 1. Experiment 1. Days from Weaning to Estrus and Number of Corpora Lutea in Primiparous (n = 35) and Multiparous (n = 10) Sows Supplemented with L-tyrosine (0 or 45.5 mg/lb BW) on the Day After Weaning

Treatment	Days to estrus[a]	No. of corpora lutea[b]
Control	5.1 ± 1 (n = 22)	16.2 ± .9 (n = 19)
Tyrosine	5.3 ± .9 (n = 23)	15.8 ± .9 (n = 15)

[a]Interval from weaning to first observed estrus.
[b]Number of corpora lutea were determined by laparotomy on d 5 after first detected estrus.

Table 2. Experiment 2. Days from Weaning to Estrus and Litter Traits of Sows Supplemented with L-tyrosine (0 or 45.5 mg/lb BW) on the Day After Weaning[a]

Item	Control	Tyrosine	SEM	P value
No. sows	61	53		
Weaning to estrus, d	4.6	6.4	.5	.01
Gestation length, d	114.2	114.2	.2	.94
No. pigs born alive	9.9	9.3	.4	.27
No. mummies	.08	.14	.05	.36
No. stillborn pigs	.56	.69	.14	.52
Total pigs born	10.6	10.1	.4	.47

[a]Body condition score and weaning date were nonsignificant covariables in these analyses.

DOES EXTRA FEED AFTER BREEDING AFFECT LITTER SIZE?

D. L. Davis

Summary

Fertility was evaluated in sows fed 4 vs 10 lb/d and gilts fed 4 vs 7.4 lb/d during the first 10 days after breeding. No effects on farrowing rate or litter traits were detected. This confirms results of a previous KSU experiment. Therefore, high feed intake after breeding may not affect fertility traits.

(Key Words: Sows, Intake, Reproductive Performance, Gestation.)

Introduction

It is generally believed that high feed intake during the period immediately after breeding is detrimental for embryo survival. We initially undertook studies to determine the nature of the problems(s) created by high feed intake, so that methods could be developed to prevent negative effects on embryo survival. However, we did not detect any effects of postbreeding feeding level on litter size (Swine Day Report of Progress, 1988, p. 22). Therefore the two experiments in this report were conducted to retest the hypothesis that higher than generally recommended amounts of feed during the first 10 d after breeding adversely affect fertility.

Procedures

Crossbred primiparous sows (Yorkshire × Hampshire × Chester White) and gilts (Yorkshire × Duroc × Hampshire) were checked once/d for estrus and inseminated artificially (AI) with semen from Duroc (sows) or Hampshire × Chester White (gilts) boars. All females were inseminated on the first and second days of estrus with semen from two or more boars. Sows came into estrus 4 to 15 d postweaning, and gilts were 7 to 8 mo old at AI. All females were placed in gestation stalls at estrus and fed individually once/d.

Experiment 1 included 27 sows that were assigned at estrus to be fed either 4 or 10 lb of a standard gestation diet. Experiment 2 included 79 gilts fed either 4 or 7.4 lb/d. In both experiments, the treatments began at first detected estrus and continued for 10 d. After d 10, all females were fed 4 lb/d of the same diet for the remainder of gestation. Approximately 30 d after AI, females were checked for pregnancy using ultrasound, and pregnant females were moved to outside lots where they were individually fed once/d for the remainder of gestation.

Results and Discussion

Similar fertility was observed in both treatments in each experiment (Table 1). In Experiment 1, 27 primiparous sows had a farrowing rate of 89%. Farrowing rate and litter size were similar for both treatments. In Experiment 2, gilts had an overall farrowing rate of 94% and farrowed an average of 9.6 pigs. No treatment effects on either farrowing rate or litter size were detected in either experiment.

Since we began our studies, two research groups in the United Kingdom have failed to observe effects of postbreeding feed intake on fertility. However, one Canadian study found that high feed intake after breeding depressed embryo survival at d 25 of pregnancy. It appears that any negative effects of feeding level are quite inconsistent compared to the advantages obtained by high feed intake (flushing) during the 2 weeks before breeding (Swine Day Reports of Progress, 1984 and 1987). Therefore, increased litter size may result from flushing, even in situations where feed intake cannot be reduced immediately after the female reaches estrus.

Table 1. Fertility of Sows and Gilts Provided Different Amounts of Feed during the 10 Days after Breeding

			Litter traits	
Feed/d, lb	No. of females	% farrowed	Total pigs farrowed (lb)	Live pigs farrowed (lb)
Experiment 1				
4	13	92 (12/13)	9.4 ± .6	9.1 ± .6 (24.5 ± 1.6)[a]
10	14	86 (12/14)	9.3 ± .6	9.2 ± .6 (26.6 ± 1.6)
Experiment 2				
4	39	92 (36/39)	9.4 ± .4 (26.7 ± 1.2)[a]	8.9 ± .4 (25.5 ± 1.3)
7.4	40	95 (38/40)	9.7 ± .4 (27.4 ± 1.1)	8.6 ± .4 (24.8 ± 1.3)

[a]Weight of the litter

THE INFLUENCE OF ADDED LYSINE DURING LACTATION ON SOW AND LITTER PERFORMANCE

J. L. Laurin, R. D. Goodband, J. L. Nelssen, R. D. Richard, and D. R. Keesecker[1]

Summary

An on-farm field study utilizing 287 crossbred sows was conducted to investigate the influence of additional dietary lysine during lactation on sow and litter performance. At farrowing, sows were randomly assigned to one of two milo-soybean meal diets containing either .65% (13.5 % CP) or .85% lysine (16.3% CP). Average sow parity was 3.75, and sows on both treatments had a similar number of pigs born alive and similar pig and litter birth weights. All litters were equalized to approximately 9.5 pigs within 24 hours following farrowing, and average lactation length was 21 d. No treatment × parity interactions were observed for any response criteria. Pig and litter weaning weights were increased from 13.10 and 114.7 to 13.65 and 120.9 lb for sows fed the .65% and .85% lysine diets, respectively. Pig survival was excellent for both groups of sows; however, survivability tended to be improved for 2nd and 4th parity sows fed the .85% lysine diet. Increased dietary lysine during lactation resulted in no difference for number days from weaning to estrus; however, the subsequent farrowing rate for the sows fed the .85% lactation diet was 75.7% as compared to 70.4% for the sows fed the .65% lysine diet. These results indicate that increased dietary lysine during lactation improved pig and litter weaning weights.

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

Introduction

In recent years, the development of a highly prolific white line sow has forced researchers and producers to re-examine current feeding strategies for the breeding herd. At present, there is little information identifying the nutritional requirements of these high producing individuals. During lactation, the primary objectives are to maximize milk production and prepare the sow for rebreeding. However, when dietary nutrients do not meet the sow's requirements, body tissues will be mobilized to meet these demands. Research at the University of Kentucky has recently evaluated the response of sows nursing 11 to 13 pigs to several dietary lysine levels. Increased pig and litter weaning weights were observed for these large litters from sows fed increasing dietary lysine protein (i.e., lysine). Based on the level of milk production, high producing sows have very high nutritional requirements. Calculation of nutrient requirements for these sows involves knowledge of daily feed intake and litter weight gain. The following example outlines the calculations used to determine daily protein intake necessary to maximize milk production and litter weight gain:

1. A 400 lb sow weans nine, 15 lb pigs after a 21 d lactation. Subtracting litter birth weight indicates that the litter gained 108 lb, or 5.1 lb per d (108/21d).

2. Each lb of litter weight gain requires 4 lb of milk; therefore, this sow is producing approximately 20.4 lb (5.1 lb × 4 lb) of milk per d during lactation.

[1]We would like to thank Keesecker Agribusiness for the use of facilities, animals, and assistance in collection of data.

3. Sow's milk is 5.25% protein, resulting in 1 lb (20.4 × 5.25%) of milk protein produced daily.

4. Conversion of dietary protein into milk protein is approximately 56%; therefore, to produce 1 lb of milk protein, this sow requires 1.8 lb (1 lb/56%) of dietary protein per d for milk production.

5. Protein requirement for maintenance of .2 lb, is added to the 1.8 lb for milk production, for a total dietary protein requirement of 2.0 lbs per day.

6. Knowing feed intake will allow determination of percentage of dietary protein. If the sow is consuming an average of 14 lb per day, then the diet must contain 14% protein (2 lb/14 lb). However, if the sow is only consuming 12 lb of feed per day or less, then the diet must contain at least 16.5% protein.

Our objective in conducting this field study was to determine if high producing sows nursing 9 to 10 pigs would be able to utilize a higher level of dietary lysine for increased milk production (measured through weaning weights) and improved rebreeding performance.

Procedures

On the day of farrowing, sows were randomly assigned to one of two milo-soybean meal diets (Table 1). Dietary lysine levels were .65% in the control diet and .85% in the experimental diet. The milo-soybean meal ratio was adjusted to achieve the desired level of dietary lysine and each diet contained 1.5 lb L-lysine-HCL. All litters were equalized and weighed within 24 hours following farrowing. The number of pigs and litter weights were also recorded at weaning. Individual feed intake was recorded daily. At weaning, sows were moved to an environmentally controlled breeding facility for estrus detection and breeding. Days from weaning to estrus and subsequent farrowing performance were recorded. All first parity sows were allowed to skip their first post-weaning estrus (vacationed) and, thus, were not included in the rebreeding data.

Results and Discussion

The number of pigs born alive, pig and litter birth weight, and number of pigs equalized/litter were similar (P>.10) at the start of the experiment. No treatment ×parity interactions (P>.10) were observed for the response criteria. Additional lysine resulted in improved pig and litter weaning weights (P<.05) for sows fed .85% lysine during lactation. Numbers of pigs weaned for the sows fed the control and high-lysine diets were 8.71 and 8.90, respectively. However, sows fed the high lysine diet had numerically higher survivability than sows fed the control diet (94.2 and 92.9%, respectively). Pig survival tended (P<.10) to be improved for 2nd and 4th parity sows fed the .85% lysine diet. There were no differences in daily feed intake between treatments; however, sows fed the .85% lysine diet tended (P<.10) to have higher feed intake. Daily lysine intakes were calculated at 38.1 and 52.2 g, respectively, for sows fed the .65% and .85% lysine diets. Days from weaning to estrus were not affected by dietary treatment. Subsequent farrowing rates were 75% for the sows fed the high lysine diet as compared to 70% for the sows fed the control diet. In conclusion, these results indicate that high producing sows, nursing 9 to 10 pigs, are able to utilize higher quantities of dietary lysine for improved milk production, as reflected in the heavier pig and litter weaning weights.

Table 1. Composition of Lactation Diets

	Lysine Level, %	
Ingredients	.65	.85
Sorghum	79.05	72.31
Soybean meal (48%)	13.37	20.25
Soy oil	3.00	3.00
Lysine-HCL	.075	.075
Monocalcium phosphate	2.34	2.22
Limestone	1.02	0.99
Vitamin premix	0.50	0.50
Sow add pack	0.50	0.50
Trace mineral premix	0.10	0.10
	100.00	100.00

Table 2. Influence of Dietary Lysine Level during Lactation on Sow and Litter Performance

	Lysine Level, %		
Criteria	.65	.85	CV
No. of litters/treatment	131	156	
No. of pigs equalized, d 1	9.42	9.48	13.9
No. pigs weaned	8.71	8.90	14.6
Pig survival, %[b]	92.89	94.17	9.9
Pig weaning weight, lb[a]	13.10	13.65	14.2
Litter weaning weight, lb[a]	114.65	120.90	20.4
Daily feed intake, lb[b]	12.9	13.5	39.7
Daily lysine intake, g	38.1	52.2	39.7
Days from weaning to estrus	6.5	7.3	78.7
Subsequent farrowing rate, %	70.4	75.7	60.6

[a]Effect of dietary lysine (P<.05).
[b]Effect of dietary lysine (P<.10).

THE EFFECTS OF AN "IDEAL PROTEIN" LACTATION DIET ON SOW AND LITTER PERFORMANCE [1]

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Summary

Four hundred lactating sows were used to determine the influence of an ideal protein lactation diet on sow productivity. Sows were fed either a 15.8% crude protein, corn-soybean meal, control diet or a 12.6% protein diet supplemented with synthetic amino acids to a 15.8% crude protein equivalent. Lactation diet had no influence on litter weaning wt (114.5 vs 114.7 lb), daily feed intake (12.5 vs 12.7 lb), pig survivability (92.3 vs 93.1%), or sow backfat loss (.11 vs .12 in). However, sows fed the ideal protein diet lost more weight than sows fed the control diet (18.6 vs 25.1 lb). These results indicate that an ideal protein diet based on synthetic amino acid additions can be effectively used during lactation without depressing sow milk production, as measured by litter weaning wt. However, the ideal protein diet did not improve sow productivity and resulted in increased sow weight loss.

(Key Words: Sow, Performance, AA, Intake, Protein)

Introduction

Ideal protein is a term used to describe a diet with a pattern of amino acids in the exact proportion required by the pig. Typical corn- or milo-soybean meal diets are formulated to the lysine requirement of the pig, because it is the first-limiting amino acid. This results in a diet with excess levels of all other essential amino acids. In theory, pigs should perform optimally if all amino acids are provided in the exact proportion to their requirements. In a true ideal protein diet, all amino acids would be equally limiting and none would be present in excess. Amino acids in excess of the pig's requirement must be deaminated and broken down, and the nitrogen must be removed from the body. The deamination and nitrogen removal process requires energy. Thus, in theory, decreasing the amount of excess amino acids that must be deaminated should conserve energy for other body functions, such as milk production, reproduction, or growth.

Lactating sows are often in a negative energy state. Milk production requires more energy than sows consume in most production units. Therefore, any dietary change that alters metabolism to conserve energy should increase production. Decreasing excess amino acids by feeding an ideal protein diet should be one means of conserving energy. Therefore, the objective of this trial was to determine the influence of an ideal protein lactation diet on sow productivity.

[1]Appreciation is expressed to Nutri-Quest, Inc. for donating synthetic amino acids used for the trial. The authors also wish to thank Dale Keesecker and Keesecker Agribusiness, Washington, KS, for use of facilities and animals.

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Procedures

At farrowing, 400 crossbred sows were randomly assigned to a 15.8% crude protein diet (Control) or a 12.6% crude protein diet supplemented with amino acids in an ideal protein ratio (Ideal). The ideal protein diet was formulated by using corn and soybean meal to meet the isoleucine requirement, with synthetic amino acids added to achieve the desired dietary levels of lysine, valine, threonine, tryptophan, and methionine (Table 1). The ideal amino acid ratio used to formulate the diets was the ratio suggested for the lactating sow by NRC (1988). This ratio, adjusted to a .8% lysine diet, and the amino acid concentrations in the experimental diets are listed in Table 2. Diets were calculated to contain .80% lysine, .9% calcium, and .8% phosphorus.

Sows were weighed and ultrasonically scanned for backfat at farrowing and weaning to determine weight and backfat loss. Litters were standardized by d 2 of lactation. Litters were weighed at farrowing and weaning. Sow were provided ad libitum access to feed during lactation, and feed intake was recorded daily.

Table 1. Composition of Experimental Diets, %

Ingredient	Control	Ideal
Corn	72.14	80.33
SBM (47% CP)	20.50	11.57
Soybean oil	3.00	3.00
Monocalcium phosphate (21% P)	2.22	2.39
Limestone	1.00	1.02
Salt	.50	.50
Vitamin premix[a]	.25	.25
Sow add pac[b]	.25	.25
Trace mineral premix[c]	.15	.15
Amino acid mix[d]	.54	—
Total	100.00	100
Calculated Analysis		
Crude protein, %	15.8	12.6
Lysine, %	.80	.80
Metabolizable energy, Mcal/lb	1533	1523

[a]Each lb of premix contains: 2,000,000 IU vitamin A, 200,000 IU vitamin D, 8,000 IU vitamin E, 800 mg menadione, 6 mg vitamin B_{12}, 1,500 mg riboflavin, 5,200 mg pantothenic acid, 9,000 mg niacin, and 30,000 mg choline.

[b]Each lb of premix contains: 70,000 mg choline, 40 mg biotine, and 300 mg folic acid.

[c]Each lb of premix contains: 50 g zinc, 50 g iron, 12 g menganese, 5 g copper, 90 mg iodine, and 90 mg selenium.

[d]Amino acid mix supplied ideal diet with .316% L-lysine HCl, .137% L-valine, .078% L-threonine, .01% L-tryptophan, and .001% L-methionine.

Table 2. Amino Acid Levels in Experimental Diets, %

Amino Acid	Ideal Ratio[a]	Control	Ideal Protein
Lysine	.80	.80	.80
Arginine	.54	1.04	.76
Histidine	.34	.43	.35
Isoleucine	.52	.68	.52
Leucine	.64	1.58	1.36
Met & Cys	.48	.57	.48
Phe & Tyr	.94	1.41	1.13
Threonine	.58	.64	.58
Tryptophan	.16	.20	.16
Valine	.80	.84	.80

[a]Ideal ratio is the ratio suggested for the lactating sow by NRC (1988) adjusted to .8% lysine. This ratio was used to formulate the ideal protein diet.

Results and Discussion

There were no parity by diet interactions for any of the response criteria. There were no differences related to diet for number of pigs born alive, after equalization, or weaned (Table 3). Piglet survivability averaged 92.7% and was not different between lactation diets. Litter birth wt and weaning wt were not affected by treatment.

Sows fed the ideal protein diet were slightly heavier at farrowing (P<.05) and lost more weight (P<.01) during lactation than sows fed the control diet. Backfat at farrowing or weaning was not affected by treatment. Feed intake increased as lactation progressed; however, diet did not influence feed intake.

The results of this trial can be viewed in two different ways. First, feeding the ideal protein diet did not decrease litter weaning wt, indicating that a portion of the protein in the lactation diet can be replaced with synthetic amino acids without influencing sow productivity. These results suggest that synthetic amino acids can be effectively used in sow lactation diets when an ideal amino acid ratio is maintained.

However, a second perspective is that sows fed the ideal protein diet should have had fewer amino acids to deaminate and, thus, more energy available for milk production. This should have resulted in increased litter weaning wt. Actually, litter weaning wt was not changed and sow wt loss increased for sows fed the ideal protein diet compared to sows fed the control diet. Several possible reasons may be cited for the failure of the ideal protein diet to improve sow productivity in this experiment. The energy savings from deamination of fewer excess amino acids may not have been great enough to increase milk production. Also, the ideal amino acid ratio listed by NRC (1988) may not be applicable to high-producing sows. Many of the amino acid requirements listed by NRC (1988) were determined using sows that weaned 7 to 8 pigs per litter. The simple upwards adjustment of all amino acids in a constant ratio may not be appropriate. Additionally, faster absorption rates for synthetic amino acids may have decreased their utilization for protein synthesis and limited the effectiveness of the ideal protein.

In conclusion, these results indicate that an ideal protein diet based on synthetic amino acid additions can be effectively used during lactation without depressing sow milk production, as measured by litter weaning wt. However, similar to the response in earlier experiments with the growing-finishing pig, formulating the lactation diet to an ideal amino acid ratio did not improve performance.

Table 3. Influence of Ideal Protein Diet on Sow Productivity

Item	Control	Ideal Protein	CV[a]
No. of sows	190	210	
Lactation length, d	20.1	20.1	10.6
Pig performance			
No. pigs born alive	9.43	9.66	24.3
No. pigs after equalization	9.67	9.62	15.9
No. pigs weaned	8.86	8.90	15.7
Pig survival, %	92.3	93.1	11.6
Litter birth wt, lb	34.4	34.5	23.9
Litter wean wt, lb	114.5	114.7	20.6
Sow performance			
Postfarrowing wt, lb[b]	470.3	479.7	9.7
Weaning wt, lb	451.8	454.5	10.5
Wt loss, lb[c]	18.6	25.1	105.8
Postfarrowing backfat, in	.95	.93	22.3
Weaning backfat, in	.84	.81	21.1
Backfat loss, in	.11	.12	110.8
Feed intake, lb/d			
Week 1	9.8	10.0	27.0
Week 2	13.1	13.6	21.9
Week 3	14.6	14.8	36.2
Overall	12.5	12.7	18.6

[a]CV = coefficient of variation.
[b]Diet effect (P<.05).
[c]Diet effect (P<.01).

THE EFFECT OF PRE-WEANING EXPOSURE TO SOYBEAN MEAL ON SUBSEQUENT POST-WEANING GROWTH PERFORMANCE IN THE EARLY-WEANED PIG [1]

K. G. Friesen, R. D. Goodband, J. L. Nelssen, F. Blecha[2], D. N. Reddy[2], P. G. Reddy[3], and B .T. Richert

Summary

Two hundred and forty pigs averaging 11.3 lb and 21 d of age were utilized to determine the effect of pre-weaning exposure to soybean meal on nursery performance. Pigs were derived from sows that were fed either a soybean meal based- or a corn gluten meal based-diet throughout gestation and lactation. Across sow treatments, pigs were stomach-infused with 6 g/d of soybean meal or placebo from d 5 to 9 of age. Treatment structuring prior to weaning allowed for comparisons between pigs immunologically sensitized to soy proteins and pigs nonsensitized to soy proteins. Nursery treatments allowed for a comparison between a diet containing known soy antigens (glycinin and beta-conglycinin) and a diet that did not contain dietary antigens (milk protein). Thus, eight nursery treatments resulted based upon sow treatment (soybean meal vs corn gluten meal diets), stomach infusion (soybean meal vs placebo), and Phase I dietary treatment (soybean meal vs milk diets). Pigs were allotted by weight and sex within sow treatment by stomach infusion group. Pig weights and feed consumption were recorded weekly for the determination of average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G). Sow treatment and infusion treatments did not cause differences in growth performance, allowing data to be analyzed for the main effect of nursery diet treatment. Phase I diets (1.4% lysine) were fed from d 0 to 14 post-weaning. During this time, ADG was increased by 18% in pigs fed a diet containing all milk protein. Average daily feed intake was decreased by 6% and F/G by 24% in pigs fed the soybean meal diet, compared to pigs fed the milk diet. Pigs fed a soybean meal diet during Phase I appeared to respond to the diet with a delayed transient hypersensitivity (DTH) to soy proteins. On d 14, all pigs were placed on a common (1.25% lysine) Phase II diet. This diet contained 22.7% soybean meal and 10% dried whey. Phase II performance was inverse to Phase I performance, with pigs fed a milk diet during Phase I having a 20% decrease in ADG, an 8% decrease in ADFI, and 14% poorer F/G than pigs fed a soybean meal diet during Phase I. These results suggest that the DTH response occurred during Phase II in pigs fed an all milk diet during Phase I. The magnitude of the DTH response was similar for pigs in both phases. The overall performance (d 0 to 35) indicated a 7% decrease in ADG, a 5% decrease in ADFI, with a 2% poorer F/G in pigs fed a milk diet during the Phase I period. These data indicate that pigs develop a tolerance to soy proteins within 2 wk post-weaning. Early-weaned pigs fed a diet devoid of soybean meal for 14 d will exhibit the same DTH response when placed on a corn-soybean meal diet as pigs fed a diet containing soybean meal immediately following weaning. This experiment also points out that prior infusion to soy protein is not necessary for a possible DTH response.

(Key Words: Pig, Starter, Subsequent Performance, Transient Hypersensitivity, Soybean.)

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[1]Appreciation is expressed to the National Pork Producers Council for partial funding of this project.

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Introduction

Research has identified a delayed transient hypersensitivity (allergic) response (DTH) to soybean protein in the early-weaned pig. Research at Kansas State University has characterized the extent of this allergic response by sensitizing the young pig (4 to 9 d of age) to soybean meal. Once the pig has been sensitized to soybean proteins, antibodies specific to soybean meal are produced by the pig to protect against future infiltrations of soy protein in the small intestine. Pigs that are weaned at 21 d of age are typically placed on a starter diet that contains varied amounts of soybean meal. At this point the antibodies specific to soy antigens mount an immune response at the intestinal level of the pig. The immune response to this antigenic infiltration results in damage to the microvilli lining of the small intestine, reducing the absorptive capacity of the intestinal tissues. Poor growth performance and possible secondary bacterial infections (*E. coli*) can result because of the intestinal damage. European research indicates that young pigs fed creep feed containing soybean meal must consume .9 to 1.1 lb of feed prior to weaning before a tolerance to soybean meal is obtained. Creep feed intakes below this amount may actually sensitize the young pig to soy proteins. When soy proteins are fed in the nursery diet, the delayed type hypersensitivity results. Thus, the purpose of this trial was to characterized the immune response from a practical approach. Data were collected to determine if young pigs require prior exposure to soybean meal, either by passive immunity from the sow or by stomach infusion, or if soybean meal in starter diets alone could trigger the immune response. The potential for a maternal transfer of antibodies to the young pig was also considered.

Procedures

Eighty crossbred sows were randomly allotted to one of two treatments at breeding: 1) milo-soybean meal diet or 2) milo-corn gluten meal diet (Table 1). Sows remained on these treatments throughout gestation and lactation. Thus, sows fed corn gluten meal were not exposed to soy proteins for 135 d. By eliminating soy exposure, a possible maternal transfer of antibodies to the young pig through the colostrum could be assessed compared to the soybean meal fed sows. On d 5 through 9 post-farrowing, six to eight pigs per litter were stomach-infused with 6 g/d of soybean meal or a placebo. These two treatments were conducted within each of the two sow treatments. Stomach infusion of soybean meal served to sensitize the young pig to soy proteins. Two hundred and forty pigs averaging 11.3 lb were weaned at 21 d of age and placed on one of two dietary treatments: 1) corn-soybean meal-lactose or 2) corn-dried skim milk-dried whey (Table 1). The final treatment structure consisted of eight treatments based upon sow treatment, infusion treatment, and nursery diet treatment. Pigs were blocked in the nursery based on nursery treatment within infusion treatment within sow treatment (Table 2).

Gestation diets were formulated to contain .5% lysine with milo and soybean meal or corn gluten meal (Table 1). The corn gluten meal diet was supplemented with 4% fish meal as an added protein source. Lactation diets were formulated to contain .65% lysine, also based on soybean meal or corn gluten meal. Phase I nursery diets were formulated to 1.4% lysine and 24.4% lactose (Table 1). A corn-soybean meal diet supplemented with 24.4% lactose was compared to a diet formulated with corn, dried skim milk, dried whey, and casein. The milk diet contained only milk products as the protein source. Pigs were switched to a common corn-soybean meal diet (1.25% lysine) with 10% dried whey on d 14 of the trial (Phase II).

Pigs were housed in an environmentally controlled nursery on wire mesh flooring. Each pen contained a self feeder and a nipple waterer to provide ad libitum access to feed and water. Four pigs were placed in each pen, with 8 replicate pens (4 ft × 5 ft) for each of the eight treatments. Pig weights and feed consumption were recorded weekly to calculate ADG, ADFI, and F/G.

Results and Discussion

Sow treatment differences (P>.10) were not detected in subsequent starter pig performance. Numerical increases in ADG (d 0-14 post-weaning) were detected for pigs reared on sows fed a corn gluten meal-based diet throughout gestation and lactation compared to a soybean meal-based diet. These results suggest a possible maternal transfer of anti-soy antibodies to the young pig. Pigs stomach-infused with soybean meal had similar ADG, ADFI, and F/G post-weaning as pigs stomach-infused with a placebo (Table 2). These results suggest that prior infusion of soy proteins is not neccessary to develop a DTH response.

Phase I nursery performance was drastically affected by dietary treatment. Average daily gain decreased (P<.01) by 18% when a soybean meal diet was fed instead of a milk diet (Table 3). Feed efficiency was 24% poorer (P<.01) for pigs fed a soybean meal diet, with a 6% decrease in feed intake (P<.05). The poor performance of pigs fed a soybean meal diet can possibly be attributed to the DTH response at the intestinal level. The 6% decrease in ADFI does not fully account for the 24% poorer F/G, indicating that soy proteins were poorly utilized by the pig.

Growth performance during Phase II (d 14-35) was inverse to that observed during Phase I (d 0-14). During this period all pigs were fed a common 1.25% lysine corn-soybean meal diet supplemented with 10% dried whey. This diet contained 22.7% soybean meal. Average daily gain for pigs fed a milk diet during the Phase I period decreased (P<.01) by 20% compared to pigs fed a soybean meal diet in Phase I. An 8% decrease in ADFI (P<.01) was detected in milk-fed pigs, whereas F/G was 14% poorer (P<.01). Exposing milk-fed pigs to soybean meal during Phase II may have caused a DTH response. The response was delayed 2 wk post-weaning in pigs fed a milk-diet during Phase I, but similar depressions in growth performance were detected during Phase II and Phase I. Pigs fed a soybean meal-based diet for the entire trial did not exhibit the DTH response a second time. It is possible that a tolerance to soy protein, allowing improved utilization, may have developed in pigs fed a soybean meal diet during Phase I.

Overall growth performance indicated increased ADG (P<.05) for pigs fed soybean meal throughout Phase I and II. Daily gains were increased by 7% for the 35 d trial. Average daily intake also increased (P<.05) for pigs fed soybean meal throughout the trial. Feed efficiency was not different for the entire trial. Excellent feed conversion for pigs fed a milk diet during Phase I negated the poor efficiency detected during Phase II. The adverse effects caused by the allergic reaction during Phase II remained evident for the overall performance in milk-fed pigs. Even though pigs had higher ADG and were more efficient on milk based diets during Phase I, pigs receiving soybean meal throughout the trial possibly developed a tolerance to soybean meal earlier than pigs fed a milk diet during Phase I. Diets containing strictly milk products as protein sources did not improve overall nursery performance, even though improved growth performance was detected during Phase I.

From this trial, the severity of a possible DTH response was observed in both the Phase I and II periods. It is evident that pigs cannot be fed diets devoid of soybean meal during Phase I without decreased growth performance from d 14-35 post-weaning. At some point, the pig has to be introduced to soy products for the development of tolerance to soy protein. Pigs introduced to soybean meal in both Phase I and II exhibited a similar allergic response, which reduced growth performance. These data suggest that a tolerance to soy protein needs to be obtained soon in the early-weaned pig. European research indicated that .9 to 1.1

lb of creep feed is required to develop a tolerance to soy protein prior to weaning. Further research is necessary to determine the amount of soybean meal needed to develop soy tolerance in the early weaned pig that has not received creep feed prior to weaning.

Table 1. Composition of Diets

	Gestation		Lactation		Phase I		Phase II
Ingredient, %	SBM[a]	CGM[a]	SBM	CGM	SBM	MILK	
Milo	86.02	80.13	80.30	61.40			
Corn					24.94	43.66	55.83
Soybean meal, (48%)	9.68		14.90		40.35		22.71
Corn gluten meal		12.24		31.00			
Fish meal		4.00		4.00			4.00
Dried skim milk						20.00	
Dried whey						20.00	10.00
Casein						7.41	
L-Lysine					.10	.15	.15
DL-Methionine					.05		
Lactose					24.40		
Soybean oil					6.00	6.00	4.00
Monocalcium P[a]	2.37	1.94	2.80	1.80	2.23	1.24	1.46
Limestone	1.03	.79	1.00	.90	.73	.49	.55
Salt	.50	.50	.50	.50	.15		.25
Vitamin premix	.25	.25	.25	.25	.25	.25	.25
Trace min. premix	.15	.15	.15	.15	.15	.15	.15
Biotin premix			.10	.10			
Selenium premix					.05	.05	.05
Copper sulfate					.10	.10	.10
Antibiotic[c]					.50	.50	.50
Total:	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis, %							
Lysine	.50	.50	.65	.65	1.40	1.40	1.25
Ca	.90	.90	.90	.90	.90	.90	.90
P	.80	.80	.80	.80	.80	.80	.80

[a]SBM = soybean meal; CGM = corn gluten meal.
[b]21% phosphorus.
[c]CSP 250.

Table 2. Nursery Growth Performance of Pigs Exposed to Soybean Meal Prior to Weaning[a]

	SBM[b]				CGM				
	SBM[d]		Placebo		SBM		Placebo		
Item	SBM[d]	MILK	SBM	MILK	SBM	MILK	SBM	MILK	CV
d 0 to 14									
ADG, lb[e]	0.47	0.63	0.48	0.67	0.50	0.66	0.45	0.69	13.0
ADFI, lb[e]	0.61	0.63	0.63	0.66	0.62	0.66	0.60	0.67	10.3
F/G[e]	1.32	1.00	1.33	0.99	1.24	1.00	1.33	0.98	9.4
d 14 to 35									
ADG, lb[e]	1.08	0.86	1.08	0.88	1.14	0.90	1.15	0.91	14.5
ADFI, lb[e]	1.72	1.52	1.79	1.62	1.80	1.69	1.78	1.69	12.0
F/G [e]	1.60	1.78	1.66	1.88	1.58	1.91	1.57	1.87	9.2
d 0 to 35									
ADG, lb[e]	0.83	0.77	0.84	0.79	0.89	0.81	0.87	0.82	12.2
ADFI, lb[e]	1.28	1.60	1.33	1.24	1.32	1.28	1.31	1.28	10.4
F/G	1.53	1.53	1.58	1.57	1.50	1.60	1.52	1.56	6.7

[a]Means calculated from 4 pigs/pen, 8 pens/treatment.
[b]Sow gestation and lactation dietary treatment; soybean meal vs corn gluten meal.
[c]Pre-weaning infusion treatment; soybean meal vs placebo.
[d]Phase I nursery diet; soybean meal vs milk.
[e]Phase I dietary treatment milk vs soybean meal ($P<.05$).

Table 3. Nursery Growth Performance Analyzed by Main Effect of Starter Diet[a]

	Phase I Dietary Treatment[b]			
Item	Milk	Soybean Meal	S.E.[c]	Percent Difference
d 0 to 14				
ADG, lb[d]	0.66	0.48	0.013	18
ADFI, lb[e]	0.65	0.61	0.012	6
F/G[d]	0.99	1.31	0.019	24
d 14 to 35				
ADG, lb[d]	0.89	1.11	0.026	20
ADFI, lb[d]	1.63	1.78	0.036	8
F/G[d]	1.86	1.60	0.028	14
d 0 to 35				
ADG, lb[e]	0.80	0.86	0.018	7
ADFI, lb[e]	1.24	1.31	0.023	5
F/G	1.56	1.53	0.018	2

[a]Means calculated from 4 pigs/pen, 32 pens/treatment.
[b]All pigs were fed a common 10% dried whey, 1.25% lysine during Phase II.
[c]Standard error of mean.
[d]Milk vs soybean meal ($P<.01$).
[e]Milk vs soybean meal ($P<.05$).

THE EFFECT OF SOY PRODUCTS WITH OR WITHOUT MOIST EXTRUSION ON STARTER PIG PERFORMANCE

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Summary

One hundred and seventy pigs, averaging 11.88 lb and 21 d of age, were utilized in a 35 d experiment evaluating the effect of moist extrusion of soy products on growth performance and nutrient digestibility. Pigs were fed one of seven experimental diets for the first 14 d of the trial. A diet containing all milk protein served as a control. Comparisons were made between pigs fed the milk control diet and diets containing either defatted soy flakes, soy protein concentrate or experimental soy protein concentrate. Treatments consisted of: 1) 20% dried skim milk, 20% dried whey; 2 and 3) defatted soy flakes with or without moist extrusion; 4 and 5) soy protein concentrate with or without moist extrusion; 6 and 7) experimental soy protein concentrate with or without moist extrusion. A common diet formulated to 1.25% lysine was fed from d 14 to 35. Weekly pig weights and feed consumption were recorded to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G). Blood serum samples were collected on d 13 and analyzed for urea nitrogen concentration. Fecal samples were collected on d 14 to determine apparent dry matter (DM) and nitrogen (N) digestibilities. A significant interaction between extrusion and protein source was detected in ADG and F/G during the first 2 wk post-weaning. Pigs fed soy proteins processed by moist extrusion had improved ADG and F/G, with the largest improvement being detected in defatted soy flakes. Dry matter and N digestibilities were increased by processing soy proteins with moist extrusion. Nitrogen utilization was also improved by utilizing moist extrusion as evidenced by decreased concentrations of blood urea nitrogen. Based on these results, soy protein utilization in starter pig diets can be improved with moist extrusion. Though a large response to extrusion was not detected in highly processed soy products (soy protein concentrate and experimental soy protein concentrate), dramatic improvements in growth performance resulted when soy flakes were processed by moist extrusion.

(Key Words: Soybean, Starter, Performance, Milk.)

Introduction

Emphasis on increasing the number of pigs weaned per sow per year, has led to a decreased weaning age over the past several years. Pigs are commonly weaned at 21 d of age, increasing the potential for a post-weaning lag or depression in growth performance. This lag period results when pigs are removed from a highly digestible, liquid diet (sow's milk) and placed on a dry diet based upon plant proteins sources (soybean meal). Research at Kansas State University has identified an intestinal allergic reaction to antigenic properties present in soy proteins. This reaction causes intestinal damage leading to malabsorption of nutrients from the small intestine. Decreased growth rate and poor feed efficiency result from nutrient malabsorption. The small intestine is also vulnerable to secondary bacterial infections (*E. coli*), because of damage to the intestinal tissues. This problem is compounded by the increasing demand of milk products for human consumption, which increases product costs. Thus, research is being conducted to find alternative products that support high growth rates for the early weaned pig.

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One such area of emphasis is further processing of soy products by moist extrusion. The goal of utilizing moist extrusion is to reduce antigenic concentrations in soy products, thus reducing the severity of the allergic reaction in the small intestine and promoting improved growth performance of early-weaned pigs.

Procedures

A total of 170 crossbred pigs, weaned at 21 d of age, averaging 11.88 lb, was utilized in a 35 d growth trial. Pigs were allotted to seven dietary treatments based upon weight, sex, and ancestry. There were five pigs per pen with five replicate pens per dietary treatment. Pigs were housed in an environmentally controlled nursery in 4 X 5 ft pens with woven wire flooring. Feed and water were offered to the pigs on an ad libitum basis.

Experimental diets were formulated to contain 1.4% lysine, 24.4% lactose, .9% calcium, and .8% phosphorus (Table 1) and fed from d 0 to 14 postweaning. Dietary treatments were arranged in a 2 X 3 factorial including a milk diet as a control treatment. Three soy proteins were utilized; defatted soy flakes, soy protein concentrate, and experimental soy protein concentrate. The factorial arrangement was completed by further processing the three protein sources by moist extrusion. Thus, the seven Phase I dietary treatments were: 1) milk protein (MP); 2 and 3) defatted soy flour with or without moist extrusion (SF and ESF, respectively); 4 and 5) soy protein concentrate with or without moist extrusion (SPC and ESPC, respectively); and 6 and 7) experimental soy protein concentration with or without moist extrusion (ExSPC and EExSPC, respectively). A common diet was fed for the Phase II period (d 14 to 35), containing 1.25% lysine and 10% dried whey. Pig weights and feed consumption were recorded weekly to determine ADG, ADFI, and F/G.

Soy proteins were processed in a Wenger X-20 single screw extruder. The extruder was maintained at a constant temperature and pressure conditions to produce a quality textured product. Extruder conditions were maintained at similar standards for all three soy proteins. The extruded products were then ground through a hammermill equipped with a 1/16 in screen for inclusion in the experimental diets.

Blood samples were collected on d 13 of the trial to determine urea nitrogen concentrations. Fecal samples were collected on d 14 to calculate DM and N digestibilities using chromic oxide (.10%) as an indigestible marker.

Results and Discussion

An improvement in ADG and F/G ($P<.06$) for the phase I period was detected when soy proteins were further processed by moist extrusion (Table 2). The largest improvement in gain and efficiency was detected when defatted soy flour was moist extruded. The moist extrusion was the first heat processing for the soy flour. Proper heat treatment has been proven to decrease antinutritional factor concentrations, improving growth performance. Extrusion of soy protein concentrate and experimental soy protein concentrate did not improve starter pig performance. These two products had already been processed to reduce concentrations of complex carbohydrates and antinutritional factors that possibly caused depressed performance in pigs fed the SF diet. Thus, an extrusion processing by protein source interaction resulted because extrusion improved the quality of soy flakes more than the quality of the two highly processed soy protein concentrates. Pigs fed the milk-based diet had higher ADG ($P<.05$) when compared to the mean of the soy protein treatments. Average daily feed intake was not affected by moist extrusion, though numerical increases of 10 to 15% were detected. An interaction ($P<.06$) occurred between moist extrusion and soy protein source for ADG and F/G. Feed efficiency was improved dramatically when defatted soy flour was processed by moist extrusion ($P<.05$). The F/G ($P<.01$) of pigs fed milk protein was better than the mean F/G of pigs fed soy proteins.

During Phase II, all pigs were fed a common diet. Performance during Phase II was not affected by Phase I treatment. Slight numerical improvements were evident for ESF compared to SF. Extrusion of either SPC or ExSPC in Phase I did not show any advantage in growth performance during Phase II.

The overall ADG indicated an interaction (P<.06) between moist extrusion and soy protein source. This interaction was due to the 20% increase in daily gain for pigs fed defatted soy flour processed by moist extrusion. Average daily feed intake was not affected by moist extrusion, although numerical increases were detected. An interaction (P<.06) between moist extrusion and soy protein source was detected for F/G. The largest improvement in efficiency was detected between SF and ESF. The efficiency of pigs fed milk protein tended to be greater (P<.01) than the mean efficiency of the pigs fed soy protein.

Nutrient digestibility was improved by moist extrusion of soy products. An interaction (P<.06) was detected between moist extrusion and protein source for both DM and N digestibility. Nitrogen digestibility was increased in SF because heat treatment reduced the antinutritional factor. Further increases in N digestibility may be related to structural changes within the protein matrix of soy products. Nitrogen utilization was also improved (P<.06) by moist extrusion, as evidenced by decreased blood urea nitrogen in pigs fed extruded soy protein diets.

These data suggest that moist extrusion can be utilized to improve the nutritional value of various soy products. Though a large response to extrusion was not detected in highly processed soy product (SPC and ExSPC), large improvements were seen when the raw soy product (SF) was moist extruded.

Table 1. Diet Composition

Ingredient, %	Milk	SF[a] ESF	SPC ESPC	ExSPC EExSPC	Phase II Common Diet
Corn	43.56	19.98	33.66	34.41	55.83
Soy protein		45.00	31.33	30.56	
Soybean meal, 48%					22.71
Fishmeal					4.00
Dried whey	20.00				10.00
Dried skim milk	20.00				
Casein	7.41				
Lactose		24.40	24.40	24.40	
Lysine-HCl	0.15				
DL-Methionine, 98%				0.03	
Soybean oil	6.00	6.00	6.00	6.00	4.00
Monocal phos, 21% P	1.24	2.09	2.15	2.17	1.46
Limestone	0.49	1.08	1.01	1.01	.55
Vitamin premix	0.25	0.25	0.25	0.25	0.25
Trace Mineral premix	0.15	0.15	0.15	0.15	0.15
Copper sulfate	0.10	0.10	0.10	0.10	0.10
Selenium premix	0.05	0.05	0.05	0.05	0.05
Salt		0.30	0.30	0.30	0.25
Antibiotic[b]	0.50	0.50	0.50	0.50	0.50
Chromic oxide	0.10	0.10	0.10	0.10	
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis, %					
Lysine	1.40	1.40	1.40	1.40	1.25
Lactose	24.40	24.40	24.40	24.40	7.20
Ca	0.90	0.90	0.90	0.90	0.90
P	0.80	0.80	0.80	0.80	0.80

[a]SF=soy flakes, ESF=extruded soy flakes, SPC=soy protein concentrate, ESPC=extruded soy protein concentrate, ExSPC=experimental soy protein concentrate, EExSPC=extruded experimental soy protein concentrate.
[b]CSP 250.

Table 2. Effect of Moist Extrusion on Starter Pig Performance, Nutrient Digestibility, and Urea Nitrogen Concentrations

Item	Milk	SF	ESF	SPC	ESPC	ExSPC	EExSPC	CV
d 0 to 14								
ADG, lb[bc]	.54	.16	.49	.47	.51	.43	.47	17.4
ADFI, lb	.65	.57	.63	.61	.72	.63	.72	14.4
F/G[cd]	1.21	4.17	1.30	1.31	1.43	1.40	1.53	33.9
d 14 to 35								
ADG, lb	1.19	1.17	1.27	1.26	1.25	1.27	1.26	7.6
ADFI, lb	2.03	1.93	2.11	2.05	2.13	2.19	2.16	7.7
F/G	1.71	1.65	1.66	1.63	1.70	1.72	1.72	3.8
d 0 to 35								
ADG, lb[c]	.93	.76	.96	.95	.95	.94	.94	8.2
ADFI, lb	1.48	1.38	1.82	1.47	1.56	1.56	1.58	7.8
F/G[cd]	1.59	1.81	1.58	1.56	1.64	1.66	1.68	3.6
Dry Matter, %[bc]	90.40	81.60	88.29	87.37	88.38	85.63	88.81	1.4
Nitrogen, %[bc]	86.43	67.43	85.02	86.80	87.51	85.60	87.16	2.5
Serum urea N, mg/dl[bc]	4.74	22.56	17.81	16.87	16.74	17.64	17.13	8.2

[a]SF=soy flakes, ESF=extruded soy flakes, SPC=soy protein concentrate, ESPC=extruded soy protein concentrate, ExSPC=experimental soy protein concentrate, EExSPC=extruded experimental soy protein concentrate.
[b]Milk vs soy protein (P<.01).
[c]Moist extrusion X protein source interaction (P<.06).
[d]Milk vs soy protein (P<.10).

EXTRUSION PROCESSING OF LOW-INHIBITOR SOYBEANS IMPROVES GROWTH PERFORMANCE OF NURSERY PIGS FED PROTEIN-ADEQUATE DIETS

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Summary

One hundred fifty weanling pigs (15.4 lb avg initial wt) were used in a 35-d growth assay to determine the effects of processing method (roasting in a Roast-A-Tron® roaster vs extrusion in an Insta-Pro® extruder) on nutritional value of soybeans with (+K) and without (-K) gene expression for the Kunitz trypsin inhibitor. Treatments were: 1) soybean meal with added soybean oil; 2) +K roasted; 3) +K extruded; 4) -K roasted; and 5) -K extruded. All diets were corn-based and formulated to 1.25% lysine for d 0 to 14 and 1.10% lysine for d 14 to 35 of the experiment. For d 0 to 14, 14 to 35, and 0 to 35, pigs fed extruded soybeans had improved ADG and F/G compared to pigs fed roasted soybeans. Digestibilities of DM, N, and gross energy were greater for diets with extruded soybeans than diets with roasted soybeans, and diets with soybean meal and soybean oil were intermediate. The response to extrusion processing was greater with -K than +K soybeans, with pigs fed extruded -K soybean having the greatest growth performance and nutrient digestibilities and lowest skinfold thickness of any treatment. Extrusion processing of +K and -K soybeans improved growth performance and nutrient digestibility in weanling pigs fed protein-adequate diets.

(Key Words: Soybeans, Process, Starter, Performance, Trypsin Inhibitor, Immunology.)

Introduction

In last year's KSU Swine Day Report (page 52), we reported that compared to nursery pigs fed conventional soybeans, pigs fed low-inhibitor soybeans had a 6% improvement in F/G and 5 and 3% improvements in digestibility of DM and N, respectively. Also, compared to roasting, extrusion processing improved ADG by 21%, F/G by 7%, DM digestibility by 6%, and N digestibility by 5%. These improvements resulted with diets that were formulated to provide only 80% of the NRC requirement for lysine to ensure that differences in protein quality would be accentuated. If the greater nutritional value of extruded low-inhibitor soybeans reported last year was due only to differences in protein quality, there should be no differences in performance for pigs given those soybean preparations in protein-adequate diets. However, if performance is still different in protein-adequate diets, some other factor(s) is also contributing to improved nutritional value. An experiment was designed to determine the effects of roasting and extrusion on nutritional value of conventional and low-inhibitor soybeans in protein-adequate diets for nursery-age pigs.

Procedures

Williams 82 soybeans with (+K) and without (-K) gene expression for the Kunitz trypsin inhibitor were either roasted or extrud-

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ed and incorporated into corn-based diets with 20% dried whey (Table 1). Treatments were: 1) soybean meal with added soybean oil; 2) +K roasted; 3) +K extruded; 4) -K roasted; and 5) -K extruded. The roasting and extrusion temperatures were those deemed usual for soybean processing, i.e., a throughput of approximately 1,000 lb/h and an average exit temperature of 245 F in a Roast-A-Tron® roaster versus a throughput of approximately 1,500 lb/h and an average barrel temperature of 290 F in an Insta-Pro® dry-extruder. All diets were formulated to provide 1.25% lysine and 1.60 Mcal DE/lb of diet for d 0 to 14 of the experiment and 1.10% lysine and 1.61 Mcal DE/lb of diet for d 14 to 35 of the experiment. The diets were formulated to be in excess of NRC (1988) requirements for lysine and protein to ensure that differences in growth performance would not be due to difference in digestibility or availability of a limiting amino acid.

One hundred fifty weanling pigs (15.4 lb avg initial wt) were fed the treatment diets in a 35-d growth assay. The pigs were housed (five pigs per pen and six pens per treatment) in an environmentally controlled nursery equipped with a woven-wire floor. Each pen had a self-feeder and nipple waterer, so feed and water could be consumed ad libitum. On d 6 of the experiment, the pigs were given intradermal injections of protein extracts from the soybean products. Results were expressed as the increase in skinfold thickness on d 7 compared to that from an injection of saline. On d 14 of the experiment, fecal samples were collected by rectal massage, pooled within pen, dried, and analyzed for DM, N, gross energy, and Cr concentrations. Apparent digestibilities of DM, N, and energy were calculated using the indirect ratio method. Response criteria were ADG; ADFI; F/G; digestibilities of DM, N, and energy; and skinfold thickness.

Results and Discussion

Chemical composition of the soybean preparations is given in Table 2. Dry matter concentrations were similar among all soybean preparations, and protein concentrations were similar to expected values for soybean meal and full-fat soybean products. Trypsin inhibitor activities were acceptably low, ranging from 1.0 to 2.8 mg/g. However, antigenic potential (i.e., glycinin and conglycinin activity) of extruded soybeans was less than half that of roasted soybeans and soybean meal.

Pigs fed roasted and extruded soybeans had greater ADG from d 14 to 35 and greater ADFI for d 14 to 35 and overall (d 0 to 35) compared to pigs fed SBM and soybean oil (Table 3). The diet with SBM and soybean oil had greater digestibilities of DM, N, and gross energy than diets with roasted and extruded soybeans, but these differences were due to the low digestibilities for diets with roasted soybeans.

For d 0 to 14, pigs fed the extruded soybeans gained 21% faster (.58 vs .48 lb) and were 25% more efficient (1.53 vs 2.05 F/G) than pigs fed roasted soybeans. Similar responses were observed for d 14 to 35, so that overall, pigs fed extruded soybeans had 13% greater ADG (.93 vs .82 lb) and were 18% more efficient (1.63 vs 1.99 F/G). Digestibilities of DM, N, and gross energy were increased by 8, 13, and 12% when soybeans were extruded versus roasted. An objective of this experiment was to determine if factors other than protein quality might have contributed to the greater nutritional value of extruded soybeans noted in last year's KSU Swine Day Report. In the present experiment, extrusion processing improved growth performance and nutrient digestibility in pigs fed +K and -K soybeans. Additionally, antigenic potential

(ELISA determination, $\log_2$) was reduced from 11 for roasted soybeans to 3.5 for extruded soybeans. Skinfold thickness was affected in a similar manner, with a mean of 1.07 mm for roasted soybeans and .73 mm for extruded soybeans. These differences in growth performance and nutrient digestibility in protein-adequate diets and the differences in skinfold thickness infer that residual anti-nutritional factors (e.g., antigenicity) are contributing to reduced nutritional value of roasted soybeans and soybean meal.

Improved nutritional value of -K versus +K soybeans was apparent primarily when they were extruded and not when roasted. Indeed, pigs fed extruded -K soybeans had numerically the greatest growth performance and nutrient digestibilities of any treatment. These responses were not anticipated for pigs fed protein-adequate diets and did not result from differences in palatability, because pigs fed +K roasted soybeans had the greatest ADFI throughout the experiment. Skinfold thickness was less for pigs fed roasted and extruded -K soybeans compared to roasted and extruded +K soybeans. Trypsin inhibitors have been reported to induce allergic responses in humans but have not been implicated as major antigenic factors in livestock. Whether the reduced skinfold thickness for pigs fed -K soybeans resulted from absence of the Kunitz trypsin inhibitor or some interaction between the glycinin and

beans with heat processing is not apparent.

In conclusion, dry-extrusion improved the nutritional value of +K and -K soybeans. Furthermore, when pigs were fed protein-adequate diets, extruded -K soybeans were of the greatest nutritional value, roasted soybeans were of the lowest nutritional value, and SBM was intermediate.

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

Ingredient, %	Soybean meal	+K roasted	-K roasted
Soybean meal	31.05	—	—
Soybean oil	2.92	—	—
Whole soybeans[b]	—	38.74	37.25
Cornstarch	4.84	—	1.44
Corn	37.36	37.36	37.36
Dried whey	20.00	20.00	20.00
Vitamins and minerals	2.98	3.05	3.10
Copper sulfate	.10	.10	.10
Antibiotic[c]	.50	.50	.50
Chromic oxide	.25	.25	.25
Total	100.00	100.00	100.00

[a]Soybean treatments, cornstarch, monocalcium phosphate, and limestone were adjusted so that all diets supplied 1.25% lysine, 1.60 Mcal DE/lb, .9% Ca, and .8% P for Phase I and 1.10% lysine, 1.61 Mcal DE/lb, .9% Ca, and .8% P for Phase II.
[b]Extruded soybeans and cornstarch were added to replace roasted soybeans on a protein basis (analyzed values).
[c]Supplied per ton of diet: 100 g chlortetracycline, 100 g sulfathiazole, and 50 g penicillin.

Table 2. Effect of Roasting and Extrusion on Chemical Composition of Conventional (+K) and Low-Inhibitor (-K) Soybeans

Item	Soybean meal	+K roasted	+K extruded	-K roasted	-K extruded
Dry matter, %	92.6	94.7	94.4	94.0	95.2
Protein, %	48.9	38.1	44.1	38.9	45.8
Trypsin inhibitor, mg/g	1.0	2.1	2.1	2.8	1.1
Glycinin activity, $\log_2$	11	10	4	11	3
$_2$	11	11	4	11	3

Table 3. Performance of Nursery Pigs Fed Conventional (+K) and Low-Inhibitor (-K) Soybeans either Roasted or Extruded[a]

Item	Soybean meal	+K roasted	+K extruded	-K roasted	-K extruded	CV
d 0 to 14						
ADG, lb[e]	.58	.53	.55	.42	.61	24.7
ADFI, lb[j]	.92	1.03	.84	.82	.89	13.9
F/G[h]	1.62	2.02	1.58	2.07	1.47	19.0
d 14 to 35						
ADG, lb[cf]	.93	1.06	1.09	1.03	1.22	11.0
ADFI, lb[cej]	1.70	2.16	1.84	2.00	2.03	10.3
F/G[h]	1.85	2.05	1.68	1.95	1.67	6.6
d 0 to 35						
ADG, lb[fi]	.79	.85	.88	.78	.97	12.5
ADFI, lb[bej]	1.39	1.71	1.44	1.53	1.57	10.2
F/G[h]	1.76	2.03	1.65	1.95	1.61	6.0
Apparent digestibility (d 14)						
DM, %[bh]	82.2	75.0	81.7	77.1	83.3	3.3
N, %[bh]	78.6	71.3	79.5	69.9	80.6	4.2
Gross energy, %[bh]	81.0	72.2	81.2	73.8	82.9	4.0
Skinfold thickness, mm[de]	.78	1.28	.82	.85	.63	71.5

[a]A total of 150 weanling pigs (five pigs/pen and six pens/treatment) were fed in a 35-d growth assay (avg initial wt of 15.4 lb).
[bc]SBM vs extruded and roasted ($P<.05$, $P<.01$, respectively).
[d]-K vs +K ($P<.10$).
[efgh]Extruded vs roasted ($P<.10$, $P<.05$, $P<.01$, $P<.001$, respectively).
[ij]-K vs +K × extruded vs roasted ($P<.10$, $P<.05$, respectively).

EVALUATION OF PORCINE BLOOD MEAL AND PLASMA, BOVINE PLASMA, AND MEAT EXTRACT AS REPLACEMENT PROTEIN SOURCES FOR DRIED SKIM MILK IN STARTER SWINE DIETS[1]

J. A. Hansen, J. L. Nelssen, and R. D. Goodband

Summary

One-hundred fifty pigs averaging 21 ± 2 d of age were utilized in a 35d growth assay to determine the efficacy of replacing the dried skim milk portion of a high nutrient-dense diet with four commercially available animal blood or meat co-products. Pigs were blocked by weight and allotted by ancestry and sex to provide six pens (five pigs/pen) per dietary treatment. Diets were randomly assigned within blocks to provide six replicate pens per treatment. The basal diet was formulated using a corn-soybean meal mixture with 20% dried skimmilk and 20% dried whey to contain 1.40% lysine, 1.0% calcium, and .90% phosphorus. Spray-dried porcine plasma protein, porcine blood meal, bovine plasma protein, and extracted meat protein were substituted on a lysine basis for dried skim milk; lactose was added to maintain 24.4% lactose. During wk 1, pigs consuming the diet with porcine plasma had 25% and 28% higher daily gain and ADFI, respectively, than those fed the skim milk based diet. There were no differences in growth observed between pigs fed diets containing dried skim milk, porcine blood meal, or bovine plasma. Maximum performance was achieved during the Phase I period by feeding porcine plasma protein. Pigs fed the meat extract diet demonstrated significantly poorer performance than pigs fed the other diets, indicating that it is not an effective replacement for skim milk based on our substitution rates. When pigs were fed a common diet during Phase II, there was a propensity for pigs consuming porcine blood during Phase I to have higher ADFI and ADG, indicating a possible diet interaction between the two phases. During the overall trial (0 to 35 d) differences were detected only between the porcine blood meal and meat extract diets. In conclusion, porcine plasma appeared to offer the potential for greatest performance during Phase I, although there may have been a protein source interaction between Phase I and Phase II diets, indicating that more research is needed to alleviate stall-out during Phase II.

(Key Words: Starter, Performance, DSM, Milk, By-product, BM.)

Introduction

Previous research at this station has indicated that improvements of up to 40% can be observed in ADG and ADFI by replacing the dried skim milk portion of a high nutrient-dense diet with porcine plasma protein. Furthermore, these differences were maintained throughout the Phase II period in which pigs were fed a common corn-soybean meal diet containing 20% dried whey. At present, no data are available concerning the feeding value of high quality spray-dried porcine blood meal on spray-dried bovine plasma, and data are limited for soluble meat protein. Because these products are commercially available, the objective of this study was to examine their feeding value based as replacements for the dried skim milk portion of the high nutrient-dense, Phase I starter diet.

[1]Appreciation is expressed to American Protein Corporation, Ames, IA, for partial support and for supplying the animal protein sources used in the research. Appreciation is also expressed to the Kansas Value Added Center for partial support of this project.

Procedures

One-hundred twenty pigs averaging 21 ± 2 d of age were utilized in a 35 d growth assay. Pigs (11.7 lb initially) were blocked by weight and allotted by ancestry and sex to provide five pens within each block (five pigs/pen). The five dietary treatments were randomly assigned within blocks, providing six replicate pens per treatment. The diets (Table 1) were formulated to contain 1.40% lysine, 1.0% Ca, and .90% P. The basal diet was formulated using a corn-soybean meal mixture with 20% dried skim milk and 20% dried whey. The porcine plasma, porcine blood meal, bovine plasma, and meat extract are commercially available (American Protein Corporation, Ames, IA) products and were substituted on a lysine basis for dried skim milk. All diets were formulated to contain at least .91% Na, .76% isoleucine, and .39% methionine (content of basal diet) or .68% methionine plus cystine. During Phase II (14 to 35 d), a common corn-soybean meal diet containing 10% dried whey and 4% menhaden fish meal was fed. It was formulated to contain 1.25% lysine, .90% calcium, and .80% phosphorus.

Digestibility of dry matter (DM) and nitrogen (N) were calculated from fecal samples obtained on d 14 using Cr_2O_3 as an indigestible marker. Pigs and feeders were weighed weekly for calculation of average daily gain (ADG), average daily feed intake (ADFI), and feed/gain (F/G). Data for the Phase I and overall trial were analyzed as a randomized block design. Phase II data were subjected to covariate analysis of variance with Phase I ADG as the covariate and diet x Phase I ADG as an interaction term. Means were separated using the Bonferroni paired t-test.

Results and Discussion

Phase I. During wk 1, pigs fed porcine plasma had 25% and 28% higher ($P<.05$) ADG and ADFI, respectively, than pigs fed porcine blood (Table 2). This difference in growth rate can be attributed to improved feed intake for pigs fed porcine plasma, because no differences were observed for feed utilization. No differences in ADG or ADFI were detected between pigs fed the porcine plasma, bovine plasma, or skim milk-based diets, indicating that all three protein sources are of similar nutritional value in Phase I starter diets. Pigs fed the meat extract diet had the poorest F/G ratio ($P<.05$), 35% poorer than those fed skim milk, and the slowest growth rates ($P<.05$).

During Phase I (0 to 14 d), pigs fed porcine plasma had 15% higher ($P < .05$) ADG than pigs on the skim milk or bovine plasma diets and 44% higher ADG ($P < .05$) than pigs fed meat extract. Similarly, the highest ADFI was observed for pigs fed porcine plasma; it was 18% higher than that of pigs fed bovine plasma, the second highest. Pigs fed porcine blood had similar ADFI to those fed the skim milk and bovine plasma diets, but growth rates were similar to those of pigs fed porcine plasma. The N in the porcine plasma diet may be less available (4% lower digestibility) to the pig than that in the porcine blood diet. Combined with the numerically better F/G, this indicates that the amino acids could have been utilized more efficiently, thus, explaining the similarity in ADG between the two diets.

The meat extract diet had the highest availability of N; however, this difference may have been due to the higher total N in the diet. Although neither urinary N nor blood urea nitrogen were measured, the biological value of the meat extract protein probably is low compared to skim milk or the blood protein products.

Phase II. Pigs were fed a common diet during Phase II to examine the effects of Phase I diet on subsequent performance. Covariate analysis of Phase II performance indicated that no interactions were observed for the entire Phase II period, although pigs fed porcine plasma tended to have poorer performance during wks 3 and 4. This may indicate a diet interaction between Phase I and II, because pigs fed porcine blood meal during Phase I had the highest growth rates and greatest ADFI (P<.05) during Phase II.

Overall Performance. Viewing the overall performance of pigs during the trial shows that performance during Phase II had the greatest impact on statistical comparisons because of the amount of gain and feed consumption achieved by the pigs. Pigs fed the porcine blood diet in Phase I consumed from 8 to 14% more feed than pigs fed the other diets. Also, pigs fed the meat extract diet had 13% lower (P<.05) ADFI overall than pigs fed the porcine blood diet. These observations suggest that pigs fed porcine plasma during Phase I went through a stall-out phase during weeks 3 and 4, resulting in the interaction between Phase I and Phase II diets.

Conclusions

Our data indicate that maximal performance can be obtained during wk 1 and Phase I by feeding porcine plasma. Spray-dried porcine blood meal and bovine plasma can effectively replace skim milk in Phase I starter diets; however, extracted meat protein does not appear to be an effective replacement based on the present substitution rate and amino acid additions. Comparing Phase I and Phase II performance indicates an apparent interaction between protein sources in each phase. The results of this trial clearly indicate that more research is needed on Phase II to alleviate the diet interactions limiting performance during that period.

Table 1. Composition of Diets

	Phase I					
Ingredient	Skim Milk	Porcine Plasma	Porcine Blood	Meat Extract	Bovine Plasma	Common Phase II
Corn	33.44	33.13	35.72	26.93	35.51	55.86
Soybean meal, 48%	16.10	16.10	16.10	16.10	16.10	22.71
Dried whey	20.00	20.00	20.00	20.00	20.00	10.00
Test protein	20.00	10.28	6.62	15.71	6.96	-
Select menhaden fish meal, 62%	-	-	-	-	-	4.00
Lactose	-	10.00	10.00	10.00	10.00	-
Soybean oil	6.00	6.00	6.00	6.00	6.00	4.00
Monocalcium phosphate, 21% P	-	2.57	.03	.48	.26	1.46
Monosodium phosphate	1.59	-	2.38	1.93	2.21	-
Limestone	1.27	.65	1.80	1.67	1.75	.55
Salt	.30	-	-	-	-	.25
L-lysine HCl, 98%	.15	-	-	-	-	.15
DL-methionine, 99%	-	.13	.11	.04	.08	-
L-isoleucine	-	-	.09	-	-	-
CSP-250[a]	.50	.50	.50	.50	.50	.50
Copper sulfate	.10	.10	.10	.10	.10	.08
Chromium oxide	.10	.10	.10	.10	.10	-
Selenium premix[b]	.05	.05	.05	.05	.05	.05
KSU vitamin premix	.25	.25	.25	.25	.25	.25
KSU trace minerals	.15	.15	.15	.15	.15	.15
Total	100.00	100.00	100.00	100.00	100.00	100.00

Table 1. Composition of Diets (Cont.)

Ingredient	Phase I Skim Milk	Phase I Porcine Plasma	Phase I Porcine Blood	Phase I Meat Extract	Phase I Bovine Plasma	Common Phase II
Calculated analysis, %						
Crude protein[c]	19.45	19.35	18.73	26.73	18.00	18.56
Lysine	1.40	1.40	1.40	1.40	1.40	1.25
Methionine	.39	.39	.39	.42	.39	.35
Methionine plus cystine	.73	.87	.71	.68	.72	.69
Tryptophane	.25	.30	.28	.22	.22	.23
Isoleucine	1.05	.82	.76	.86	.65	.87
Threonine	.92	1.03	.90	.96	1.02	.82
Calcium	1.01	.99	.99	.99	.99	.90
Phosphorus	.90	.90	.90	.90	.90	.80
Sodium	.91	.91	.91	.91	.91	.25
Lactose	24.40	24.40	24.40	24.40	24.40	7.20

[a]Provided 5 g chlortetracycline, 5 g sulfathiazole, and 2.5 g penicillin per lb complete diet.
[b]Provided .3 ppm Se in complete diet.
[c]Analyzed content.

Table 2. Effect of Protein Source on Pig Performance[a]

Item	Skim Milk	Porcine Plasma	Porcine Blood	Meat Extract	Bovine Plasma	SEM[b]
Week 1 (0 to 7 d)						
ADG, lb	.71[cd]	.79[c]	.63[d]	.49[e]	.69[cd]	.02
ADFI, lb	.68[cd]	.83[c]	.65[d]	.64[d]	.72[cd]	.03
Feed/gain	.96[c]	1.05[c]	1.02[c]	1.30[d]	1.04[c]	.03
Phase I (0 to 14 d)						
ADG, lb	.72[c]	.83[d]	.75[cd]	.58[e]	.72[c]	.02
ADFI, lb	.86[c]	1.10[d]	.89[c]	.90[c]	.93[c]	.04
Feed/gain	1.19[c]	1.32[cd]	1.19[c]	1.56[d]	1.29[cd]	.07
Digestibility (d 14), %						
DM	73.78	72.65	71.70	71.00	72.31	1.19
N	78.28[cd]	74.92[c]	78.89[cd]	81.29[d]	76.16[cd]	1.39
Phase II (14 to 35 d)						
ADG, lb	1.08	1.06	1.22	1.12	1.14	.04
ADFI, lb	1.88[c]	1.86[c]	2.21[d]	1.96[c]	1.98[c]	.05
Feed/gain	1.75	1.75	1.81	1.74	1.74	.04
Overall (0 to 35 d)						
ADG, lb	.94[cd]	.97[cd]	1.03[c]	.91[d]	.97[cd]	.03
ADFI, lb	1.47[c]	1.55[cd]	1.68[d]	1.53[cd]	1.56[cd]	.03
Feed/gain	1.58	1.60	1.63	1.70	1.61	.04

[a]Values are means of six replicate pens containing five pigs each (initially 11.63 lb; 35 d trial).
[b]Pooled standard error of the pen means.
[cde]Means in the same row with different superscripts are different ($P < .05$).

COMPARISON OF PROTEIN SOURCES FOR PHASE II STARTER DIETS[1]

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Summary

A total of 432 weanling pigs (initially 15.3 lb and 21 d of age) was used in a growth trial to compare various protein sources in the Phase II starter diet. During Phase I (0 to 7 d postweaning), all pigs were fed a common high nutrient density diet containing 1.5% lysine, 10% porcine plasma, 10% lactose, and 20% dried whey. During Phase II (7 to 28 d postweaning), pigs were fed one of six experimental diets. All Phase II diets contained 10% dried whey and were formulated to 1.18% lysine. The positive control diet contained 4% menhaden fish meal (FISH). Synthetic amino acids were used to replace fish meal to form an ideal protein, negative control diet (AA). Spray-dried porcine plasma (SDPP), spray-dried blood meal (SDBM), soy protein concentrate (SPC), and extruded soy protein concentrate (ESPC) replaced fish meal on a lysine basis to form the other four diets. During the grower phase (28 to 56 d postweaning), all pigs were fed a common 1.1% lysine, milo-soybean meal diet. Average daily gain (lb), ADFI (lb), and F/G during Phase I were .39, .53, and 1.41, respectively. During Phase II, SPC and ESPC effectively replaced fish meal as a protein source; however, pigs fed diets containing the spray-dried blood products (SDPP or SDBM) gained faster than pigs fed the other four diets. Pigs fed the diet containing synthetic amino acids had poorer feed conversion than pigs fed diets containing the intact protein sources. Pigs fed the diet containing SDBM during Phase II gained faster during the subsequent grower phase than pigs fed the other diets. Based on these results and earlier research, optimal staging of starter diets includes using SDPP in Phase I and SDPP or SDBM in Phase II.

(Key Works: Starter, Performance, By-products, Protein, Sources.)

Introduction

Previous research at Kansas State University has concentrated on the utilization of SDPP, SDBM, and further processed soybean products (SPC and ESPC) in high nutrient density diets for the early-weaned pig. This research indicated that SDPP was superior to the other protein sources for the Phase I diet. Throughout this research, the Phase II diet has received little attention. A typical Phase II diet recommended by Kansas State University contains 10% dried whey and 3 to 5% menhaden fish meal. This trial was conducted to compare alternative protein sources in a Phase II starter diet.

[1]Appreciation is expressed to American Protein Corporation, Ames, IA, for partial financial support and to Feed Specialties, Inc., Des Moines, IA for donating feed ingredients for the trial. The authors wish to thank Louis Russell, Feed Specialties, Inc. for technical assistance and Dale Keesecker and Keesecker Agribusiness, Washington, KS, for use of facilities and animals.

[2]Extension Specialist, Livestock Production and Management, Northeast; Northeast Area Extension Office, 1515 College Ave., Manhattan, KS 66502.

Procedures

A growth trial utilizing 432 weaned pigs (initially 15.3 lb and 21 d of age) was conducted to compare protein sources in a Phase II diet. At weaning, pigs were blocked by weight and allotted by litter and sex to the six experimental treatments. During Phases I (0 to 7 d postweaning) and II (7 to 28 d postweaning), pigs were housed 12 per pen (6 pens per treatment) in an environmentally controlled nursery with woven wire flooring and allowed ad libitum access to feed and water. Feed consumption and individual pig weights were recorded weekly to determine ADG, ADFI, and F/G. On d 28 postweaning, pigs were moved to an environmentally controlled grower room with slatted concrete floors. Pigs were weighed at the completion of the grower phase (d 56) to determine ADG during the grower phase (28 to 56 d postweaning).

During Phase I (0 to 7 d postweaning), all pigs were fed a common high nutrient density starter diet containing 10% SDPP, 10% lactose, and 20% dried whey (Table 1). The Phase I diet was formulated to contain 1.5% lysine, .9% calcium, and .8% phosphorus. Pigs were switched to Phase II diets on d 7 postweaning. All Phase II diets (Table 1) contained 10% dried whey and were formulated to 1.18% lysine, .9% calcium, and .8% phosphorus. The positive control diet contained 5% menhaden fish meal (FISH). Synthetic amino acids (L-lysine HCL and DL-methionine) replaced fish meal to form an ideal protein, negative control diet (AA). Spray-dried porcine plasma (SDPP), spray-dried blood meal (SDBM), soy protein concentrate (SPC), and extruded soy protein concentrate (ESPC) replaced fish meal on a lysine basis to form the other four diets. A constant level of soybean meal was maintained in all Phase II diets. Diets were fed as 1/8 in. pellets. During the grower phase, all pigs were fed a common, milo-soybean meal diet that was formulated to 1.1% lysine and provided in a meal form.

Results and Discussion

Starter Phases I and II. During Phase I, pigs gained .39 lb/d consumed .53 lb of feed per d and had a feed conversion (F/G) of 1.41. During the first wk after pigs were switched to Phase II diets (7 to 14 d postweaning), pigs fed the diets containing blood products (plasma or blood meal) gained faster and consumed more feed than pigs fed the other four diets ($P < .01$; Table 2). The advantage in gain was maintained throughout Phase II (7 to 28 d postweaning), resulting in more total gain ($P < .06$) for pigs fed the diets containing blood products than pigs fed the other diets. The improved response to diets containing spray-dried blood products appears to be due to their ability to increase feed intake. The reason that spray-dried blood products increase feed intake in early-weaned pigs is unknown.

Extrusion processing of SPC improved daily gain and feed conversion only during the first wk of Phase II ($P < .08$). Cumulatively, pigs fed diets containing SPC and ESPC had similar daily gain and feed efficiency. Their performance also was similar to that of pigs fed the diet containing fish meal. Replacing fish meal with synthetic amino acids on an ideal protein basis resulted in similar cumulative daily gain; however, pigs fed the diet containing fish meal had improved feed efficiency as compared to pigs fed the AA diet.

Grower Phase. Pigs fed the diet containing SDBM during Phase II gained faster ($P < .03$) during the subsequent grower phase than pigs fed the diets containing the other protein sources. As a result, pigs fed the diet containing SDBM during Phase II were heavier ($P < .03$) at the end of the grower phase than pigs fed the other diets.

Conclusion. These results indicate that SDPP, SDBM, SPC, or ESPC can effectively replace fish meal on an equal lysine basis in Phase II diets. Maximal performance in Phase II was obtained when the diet contained SDPP or SDBM. Staging of protein sources such that SDPP was present in the Phase I diet and the Phase II diet contained SDBM resulted in improved subsequent performance in the grower phase. Based on these results and earlier research, optimal staging of starter diets includes using SDPP in Phase I and SDPP or SDBM in Phase II.

Table 1. Composition of Diets

Item, %	Phase I[a]	Phase II Treatment[b]					
		AA	Fish	SDPP	SDBM	SPC	ESPC
Corn	32.63	56.43	52.74	52.85	54.27	51.12	51.12
Soybean meal (47% CP)	19.34						
Soybean meal (44% CP)		25.23	25.23	25.23	25.23	25.23	25.23
Menhaden fishmeal			5.00				
Plasma protein	10.28			3.88			
Blood meal					2.49		
Soy protein concentrate (SPC)						5.74	
Extruded SPC							5.74
Dried whey	20.00	10.00	10.00	10.00	10.00	10.00	10.00
Lactose	10.00						
Soybean oil	3.00	4.00	4.00	4.00	4.00	4.00	4.00
Monocalcium phosphate (18% P)	2.47						
Dicalcium phosphate (21% P)		1.93	1.29	1.95	1.92	1.77	1.77
Limestone	.65	.83	.46	.81	.81	.86	.86
FOA 390	1.00						
Mecadox		.50	.50	.50	.50	.50	.50
Salt		.25	.25	.25	.25	.25	.25
Vitamin premix	.25	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15	.15
Copper Sulfate	.10	.08	.08	.08	.08	.08	.08
Selenium premix	.05	.05	.05	.05	.05	.05	.05
L-lysine		.29					
DL-Methionine	.08	.02					
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis, %							
Crude protein	20.1	17.5	19.9	19.5	19.2	20.5	20.5
Lysine	1.50	1.18	1.18	1.18	1.18	1.18	1.18
Methionine	.39	.27	.33	.27	.27	.29	.29

[a]All pigs were fed the Phase I diet from d 0 to 7 postweaning then switched to their experimental Phase II diets from d 7 to 28 postweaning.
[b]AA = amino acids, Fish = fish meal; SDPP = spray-dried porcine plasma, SDBM = spray- dried blood meal, SPC = soy protein concentrate, ESPC = extruded soy protein concentrate.

Table 2. Influence of Phase II Protein Source on Pig Performance[a]

	Phase II Treatment[b]						
Item	AA	Fish	SDPP	SDBM	SPC	ESPC	CV
d 7-14							
ADG, lb[cde]	.45	.56	.67	.63	.47	.57	17.1
ADFI, lb[cf]	.83	.82	.98	.91	.87	.87	9.2
F/G	2.00	1.64	1.55	1.59	2.14	1.67	24.6
d 7-28							
ADG, lb[g]	.87	.87	.94	.92	.87	.89	7.4
ADFI, lb[h]	1.39	1.32	1.41	1.40	1.35	1.36	6.3
F/G[e]	1.61	1.52	1.51	1.53	1.56	1.53	4.4
Phase II							
Total Gain, lb[g]	18.3	18.3	19.7	19.3	18.2	18.7	7.4
Grower phase							
ADG, lb[i]	1.21	1.20	1.23	1.33	1.25	1.22	7.0
Total gain, lb[i]	33.9	33.7	34.6	37.3	34.9	34.3	7.0
Pig wt, lb							
d 28[g]	36.3	36.4	37.8	37.4	36.3	36.8	3.8
d 56[gi]	70.1	70.3	72.4	74.7	71.3	71.0	3.5

[a]All pigs were fed a common diet from d 0 to 7 postweaning. Values are means of six pens containing 12 pigs per pen.
[b]See Table 1.
[c]Blood products vs others, (P<.01).
[d]SPC vs ESPC, (P<.08).
[e]Amino Acids (AA) vs others, (P<.02).
[f]Fish meal vs others, (P<. 07).
[g]Blood products vs others, (P<.06).
[h]Blood products vs others, (P<.14).
[i]SDBM vs others, (P<.03).

EFFECTS OF SOY LECITHIN AND DISTILLED MONOGLYCERIDE IN COMBINATION WITH TALLOW ON NUTRIEN DIGESTIBILITY, SERUM LIPIDS, AND GROWTH PERFORMANCE IN WEANLING PIGS

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Summary

Four hundred twenty pigs (21 d of age and 12.3 lb avg initial wt) were used to determine if adding soybean oil, lecithin, and monoglyceride to diets containing tallow affects nutrient digestibility, serum lipids, and growth performance. Treatments were: 1) a high nutrient density diet (HNDD) with 10% soybean oil; 2) HNDD with 10% tallow; 3, 4, and 5) diet 2 with 9% tallow and 1% soybean oil, lecithin, and monoglyceride, respectively. Adding soybean oil, lecithin, and monoglyceride to tallow increased digestibility of total fat, long-chain saturated fatty acids, and medium-chain fatty acids, but reduced serum concentrations of triglycerides and total, HDL (high density lipoprotein), and LDL (low density lipoprotein) cholesterol. From d 0 to 14, pigs fed soybean oil had greater ADG and ADFI than pigs fed the other treatments, and pigs fed tallow without emulsifiers had the lowest ADFI. From d 0 to 7 and 0 to 14, pigs fed diets with lecithin had improved F/G compared to pigs fed monoglyceride. For d 0 to 35, fat source or emulsifier treatment did not affect growth performance. The addition of emulsifiers increased digestibility of tallow but had only small effects on growth performance early in the nursery phase.

(Key words: Starter, Digestibility, Growth, Soybean oil, Tallow, Lecithin, Monoglyceride.)

Introduction

Early-weaned pigs have unique needs for nutrient sources and concentrations in their diet. Milk products and fat sources have become common additives to increase the nutrient density of diets and reduce post-weaning lag in performance. Although addition of fat to starter diets generally increases performance for the overall nursery phase, it has not eliminated the growth lag typically observed for the first 1 to 2 wk post-weaning. Fat digestibility increases with time post-weaning, and animal fats are less digestible than those of vegetable origin. Those responses have been attributed to the high degree of saturation and long chain length of animal fats, factors that decrease micelle formation. In young pigs, capacity of the small intestine to absorb micellar lipid exceeds normal influx into the gut. Therefore, entry of fatty acids into the micellar phase has been implicated as limiting fatty acid digestibility rather than absorption of fatty acids from the micelles into the intestinal mucosa. Emulsifying agents promote incorporation of fatty acids into micelles and should increase digestibility of fat. The objective of the present study was to determine the effects of feeding exogenous emulsifiers in combination with tallow on digestibility of nutrients, serum lipids, and growth performance in weanling pigs.

Procedures

A total of 420 pigs (21 d of age and 12.3 lb avg initial wt) was allotted on the basis of sex, weight, and ancestry to five treatments in a randomized complete block design. Treatments

[1]Department of Grain Science.

were: 1) HNDD with 10% added soybean oil; 2) HNDD with 10% added tallow; 3, 4, and 5) diet 2 with 9% tallow and 1% soybean oil, lecithin[2], and monoglyceride[3], respectively. Orthogonal c-onstrasts were used to separate treatment means. Treatment comparisons were: 1) soybean oil vs all other treatments; 2) tallow vs tallow plus soybean oil, lecithin, and monoglyceride; 3) tallow plus soybean oil vs tallow plus lecithin and monoglyceride; 4) tallow plus lecithin vs tallow plus monoglyceride.

Pigs were housed (seven per pen) in an environmentally controlled nursery with 4 ft × 5 ft pens and woven wire flooring. Pigs were allowed to consume feed and water ad libitum during the 35-d growth assay, and all diets were pelleted. The Phase 1 and Phase 2 basal diets are given in Table 1. When soybean oil, lecithin, and monoglyceride were added to tallow, they were rigorously blended prior to addition to diets. Pigs and feeders were weighed weekly to determine ADG, ADFI, and F/G. On d 13 and 14 of the experiment, fecal samples were collected by rectal massage. The samples were pooled within pen; lyophilized; and analyzed for N, DM, GE, Cr, and fatty acids. Also on d 14, blood samples were collected from all pigs, and serum was harvested and pooled within pen. The pooled sera were analyzed for triglycerides; non-esterified fatty acids (NEFA); and total, HDL, and LDL cholesterol.

Table 1. Composition of Basal Diets[a]

Ingredient, %	Phase 1	Phase 2
Corn	25.82	43.19
SBM (48% CP)	21.20	28.10
Dried skim milk	20.00	—
Dried whey	20.00	20.00
Fat[b]	10.00	5.00
Monocalcium phosphate	1.12	1.65
Limestone	.51	.86
Lysine-HCl	.10	.10
Salt	—	.10
Vit/Min/ Antibiotic[c]	1.00	1.00
Chromic oxide	.25	—

[a]Diets were formulated to supply 1.5% lysine, .9% Ca, and .8% P in Phase 1 and 1.25% lysine, .9% Ca, and .8% P in Phase 2.
[b]Fat sources were soybean oil, tallow, and 9% tallow with 1% soybean oil, lecithin, or monoglyceride.
[c]Provided the following per ton of complete diet: 100 g chlortetracycline, 100 g sulfathiazole, and 50 g penicillin.

Results and Discussion

Chemical analyses of the fat sources and emulsifiers are given in Table 2. The fatty acids in soybean oil were primarily long-chain (> C 14) and unsaturated, with 86% as 18:1, 18:2, and 18:3. Tallow also was essentially long-chain fatty acids (78%) of which half were saturated. The fatty acid profile of lecithin was similar to that of soybean oil, as might be expected, because it was a soybean product. The monoglyceride also was a soybean product, but the fatty acid composition was changed to 65% stearic acid (C 18:0) by a saturation process and was predominately a ceride. The monoglyceride was a dry powder.

Pigs fed soybean oil had the greatest digestibilities of total fatty acids, long-chain unsaturated fatty acids, and long-chain saturated fatty acids (Table 3). Addition of soybean oil, lecithin, and monoglyceride to tallow increased digestibilities of total fatty acids and long-chain saturated fatty acids. Unsaturated:saturated fatty acid ratios (U/S) were: 5.6:1, 1.3:1, 1.4:1, 1.3:1 and 1.1:1 for diets with soybean oil; tallow; and tallow plus soybean oil, lecithin, and monoglyceride, respectively. The differences observed in fatty acid digestibility between soybean oil and tallow treatments could be related to the greater U/S for soybean oil and the greater fat digestibility that is associated with increased U/S. However, differences in fatty acid digestibility between diets with tallow and diets with tallow plus soybean oil, lecithin, and monoglyceride cannot be explained by different U/S, adding support to the argument that these additions increased emulsification and, thus, digestibility of tallow. Digestibilities of N, DM, and GE were not affected by treatment.

Pigs fed soybean oil had the lowest serum triglycerides; NEFA; and total, HDL, and LDL cholesterol. Adding soybean oil, lecithin, and monoglyceride to tallow reduced serum triglycerides; NEFA; and total, HDL, and LDL cholesterol. Lecithin and monoglyceride additions to tallow tended to decrease serum triglycerides more than soybean oil. Serum HDL:LDL ratio was not affected by treatment.

From d 0 to 7, ADG was not affected by treatment, although pigs fed soybean oil had numerically the greatest ADG, and pigs fed tallow, the lowest (Tabel 4). Daily feed intake was greater for pigs fed soybean oil than those fed other treatments and was improved with the addition of soybean oil, lecithin, or monoglyceride to tallow. Pigs fed diets with lecithin had improved F/G compared to pigs fed diets with monoglyceride.

From d 0 to 14, pigs fed soybean oil had greater ADG than pigs fed other treatments, pigs fed tallow tended to have the lowest ADG, and pigs fed tallow plus the emulsifiers tended to have intermediate ADG. Addition of lecithin to tallow increased ADG by 6%. Feed intake was greater for pigs fed soybean oil compared to pigs fed other treatments, and addition of soybean oil, lecithin, and monoglyceride to tallow increased ADFI. Addition of lecithin to tallow improved F/G compared to addition of monoglyceride.

From d 0 to 35, growth performance was not affected by treatment. This response indicates that as pigs get older, differences in saturation of fat sources become increasingly less important.

In conclusion, benefits from adding fat to diets for early-weaned pigs (21 d of age and less) are inconsistent, and the fat source chosen seems to have an effect. In the present experiment, soybean oil was superior to tallow, but addition of soybean oil, lecithin, and monoglyceride to tallow improved digestibility of fat. Furthermore, diet costs were reduced by using emulsified animal fat compared to soybean oil.

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[2]Lecithin was Centrol 3F UB, Central Soya Company, Fort Wayne, IN.

[3]Monoglyceride was Myverol 18-06, Eastman Chemical Products, Inc., Eastman-Kodak Co., Kingsport, TN.

Table 2. Chemical Analysis of Fat Sources and Emulsifiers

Item	Soybean oil	Tallow	Lecithin	Monoglyceride
Moisture, %	.14	.12	.65	.51
Peroxide value, mEq/lb	1.81	2.70	5.68	.81
Acetone insolubles, %	.26	.32	62.77	24.65
Unsaponifiable matter, %	1.10	.26	4.26	1.35
Esterified fatty acids, %	79.52	81.83	45.68	28.87
Fatty acids, %[a]				
C 8:0	.00	.00	.00	.00
C 10:0	.00	.03	.00	.00
C 12:0	.00	.00	.37	.00
C 14:0	.06	2.79	.05	.07
C 16:0	7.86	21.31	10.13	7.88
C 16:1	.06	3.00	.02	.00
C 18:0	3.57	17.63	3.00	64.91
C 18:1	19.09	33.98	10.47	.00
C 18:2	58.70	1.81	52.94	.03
C 18:3	8.50	.39	7.87	.72

[a]Number of carbon atoms and double bonds are designated to the left and right of the colon, respectively.

Table 3. Effect of Fat Source, Fat Blends, and Emulsifiers on Apparent Digestibility of Nutrients and Serum Lipids in Weanling Pigs[a]

Item	Soybean oil	Tallow	Tallow + soyoil	Tallow + lecithin	Tallow + monoglyceride	CV
Apparent digestibility, %						
Total fatty acids[hi]	94.2	80.8	86.8	85.4	85.0	6.3
Long-chain unsaturated fatty acids[bf]	96.0	91.8	93.8	93.8	93.2	3.3
Long-chain saturated fatty acids[cfj]	81.4	63.4	74.2	72.2	74.2	13.2
Medium-chain fatty acids[dfi]	97.5	93.0	95.7	95.2	94.8	2.7
N[l]	86.5	85.9	86.8	87.7	87.1	3.1
GE[l]	89.4	87.4	88.1	88.7	88.5	3.2
DM[l]	88.7	88.4	88.4	88.9	88.8	2.4
Serum lipids						
Triglycerides, mg/dL[gk]	41.7	57.7	51.7	47.3	44.8	14.2
NEFA, mEq/L[ek]	.21	.33	.25	.24	.26	24.2
Total cholesterol, mg/dL[gj]	85.7	102.6	94.7	96.0	91.1	7.5
HDL cholesterol, mg/dL[ei]	30.3	35.4	33.7	32.1	31.7	10.0
LDL cholesterol, mg/dL[fi]	55.4	67.2	61.0	63.9	59.4	10.2
HDL:LDL ratio[l]	.55	.53	.55	.50	.53	14.2

[a]Seven pigs/pen and six pens/treatment, with an avg initial wt of 12.3 lb/pig.
[b]Fatty acids were C16:1, C18:1, C18:2 and C18:3.
[c]Fatty acids were C16:0 and C18:0.
[d]Fatty acids were C8, C10, C12 and C14.
[efgh]Soy oil vs other treatments ($P<.10$, $P<.05$, $P<.01$, $P<.001$, respectively).
[ijk]Tallow vs tallow + soy oil, lecithin, and monoglyceride ($P<.10$, $P<.05$, $P<.01$, respectively).
[l]No treatment effect ($P>.32$).

Table 4. Effect of Fat Source, Fat Blends, and Emulsifiers on Growth Performance of Weanling Pigs[a]

Item	Soybean oil	Tallow	Tallow + soyoil	Tallow + lecithin	Tallow + monoglyceride	CV
d 0 to 7						
ADG, lb[i]	.61	.55	.58	.59	.58	12.8
ADFI, lb[ce]	.64	.56	.59	.59	.62	11.1
F/G[g]	1.05	1.02	1.02	1.00	1.07	8.8
d 0 to 14						
ADG, lb[b]	.70	.63	.63	.67	.64	14.4
ADFI, lb[dfg]	.84	.71	.77	.78	.83	9.4
F/G[h]	1.20	1.13	1.22	1.16	1.30	12.1
d 0 to 35						
ADG, lb[i]	.95	.96	.96	.99	.98	9.2
ADFI, lb[i]	1.57	1.53	1.60	1.64	1.63	7.3
F/G[i]	1.65	1.59	1.67	1.66	1.66	10.2

[a]Seven pigs/pen and six pens/treatment, with an avg initial wt of 12.3 lb/pig.
[bcd]Soybean oil vs other treatments ($P<.10$, $P<.05$, $P<.01$, respectively).
[ef]Tallow vs tallow + soy oil, lecithin, and monoglyceride ($P<.05$, $P<.01$, respectively).
[gh]Lecithin vs monoglyceride ($P<.10$, $P<.05$, respectively).
[i]No treatment effect ($P>.11$).

OPTIMUM PARTICLE SIZE OF CORN AND HARD AND SOFT SORGHUM GRAIN FOR NURSERY PIGS AND BROILER CHICKS

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Summary

A total of 240 weanling pigs (avg initial wt of 11.7 lb) was used to determine the effects of particle size of corn and two sorghum genotypes on growth performance. In addition to the pig feeding experiment, 420 broiler chicks (avg initial wt of .15 lb) were fed the same grain treatments to determine if they were a reliable model for the effects of diet particle size on nursery pig performance. Milling characteristics of the cereal grains were measured. Treatments were corn, hard endosperm sorghum, and soft endosperm sorghum, ground to particle sizes of 900, 700, 500, and 300 µm (geometric mean), with a 3 × 4 factorial arrangement of treatments. In general, reducing particle size increased electrical energy required for milling and decreased production rate. However, there were differences among the grain sources for energy required for milling and production rates, e.g., grinding the sorghums to 500 µm took less energy than grinding corn to 900 µm. In starter pigs, the most efficient gains were achieved at 300 µm for d 0 to 7, 300 to 500 µm for d 0 to 14, and at 500 µm for d 0 to 35. It should be noted that the pig diets were in pelleted form, so problems with bridging and reduced flowability were not a concern with the finely ground grain sources. Overall, pigs fed diets containing corn grew faster, consumed more feed, and were more efficient than those fed sorghum. When compared at their optimum particle sizes, hard and soft sorghum supported ADGs that were 80 and 84% that of corn, and efficiencies of gain that were 96% that of corn. For broiler chicks, reducing particle size of corn below 900 µm did not improve gain to d 21, but grinding sorghum to 500 to 700 µm did improve gain. Efficiency of gain also was improved more with fine grinding of sorghum than corn. Optimum particle sizes for F/G were 300 and 500 µm for hard and soft sorghum, respectively. It is important to note that relative to corn, at 900 µm feeding values for chicks fed hard and soft sorghums were 92%, but at the optimum particle size for each grain, relative feeding values for hard and soft sorghum were 99% that of corn. These data suggest that sorghums can equal corn in feeding value for broiler chicks when milled to their optimum particle size, and that as pigs and chicks get older, optimum particle size increases. However, starter pigs fed corn had 15 to 20% greater ADG and 4% greater efficiency of gain than pigs fed the sorghums.

(Key Words: Particle size, Corn, Sorghum, Endosperm Hardness, Starter, Broiler Chicks.)

Introduction

Cereal grains are typically processed before they are incorporated into diets for swine. This processing nearly always involves grinding in a hammermill or roller mill to reduce particle size and, thus, improve nutrient digestibility. However, finely ground grains have been implicated as a cause of stomach ulcers in growing-finishing pigs. This occurs as the result of increased fluidity of stomach contents, which greatly increases contact of acid and enzyme

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secretions from the lower stomach with the relatively unprotected upper region of the stomach. Most research investigations of ulceration in the pig stomach have been done with finishing pigs fed corn and wheat. The research reported herein concerns the effects of particle size reduction on growth performance and gastrointestinal morphology of starter pigs fed corn and sorghums with different endosperm hardness. Additionally, comparable measurements of growth aned intestinal morphology were made on broiler chicks to determine how closely chick assays parallel growth in young pigs. If data from chick growth assays can be extrapolated to nursery-age pigs, this would greatly increase the pool of knowledge available to swine producers and add many options for researchers.

Procedures

Corn and two sorghum grains that differed in endosperm hardness were ground to four particle sizes (900, 700, 500, and 300 µm). This resulted in a 3 × 4 factorial arrangement of treatments. When processed, the three grain sources were between 12.5 and 13% moisture. Great effort was taken to ensure that targeted particle sizes were obtained and that particle sizes between grains were constant. The three coarser particle sizes (900, 700, and 500 µm) were obtained with a roller mill, and the finest particle size (300 µm) was obtained with a hammermill by grinding through a 1/16" and then a 3/64" screen. The roller mill settings were determined by setting the rolls, processing grain under full motor load, sampling the milled grain, and calculating mean particle size. The rolls were adjusted based on the particle size determination, and the process was repeated until the targeted particle size was achieved. Electrical energy consumption and production rate were recorded to allow calculation of electrical energy cost per ton of grain processed.

Diets were formulated with corn, and the sorghums were substituted for corn on a lb per lb basis. The diets were fed in pelleted form to the pigs and meal form to the broiler chicks. Energy consumption, pellet durability, and production of fines were recorded for the pelleted diets. Response criteria for the experiment were ADG, ADFI, F/G, and changes in intestinal morphology (e.g., lesions in the stomach of pigs; wt, and lesions of the proventriculus and gizzard of chicks).

A total of 240 weanling pigs, with an avg initial wt of 11.7 lb, was used in a 35-d growth assay. The pigs were allotted, based on ancestry, sex, and wt, to the 12 grain treatments. The pigs were housed (five pigs/pen and four pens/treatment) in an environmentally controlled nursery with 4 ft × 5 ft pens. Feed and water were consumed ad libitum, and pig and feeder weights were recorded weekly. Composition of the experimental diets is given in Table 1. At the end of the growth assay, five pigs from the 900 and 300 µm treatments of each grain source were sacrificed to evaluate stomach morphology.

For comparison of pig and chick growth performance, 420 broiler chicks (7 d of age and .15 lb avg initial wt) were used in a 21-d growth assay (five chicks/cage and seven cages/treatment). Chicks were randomly allotted to the 12 dietary treatments based on sex and weight. Diets were formulated to contain at least 110% of NRC for all essential nutrients. Composition of the diets is given in Table 1. Feed and water were consumed ad libitum, and chick and feed weights were recorded weekly. At conclusion of the growth assay, 15 chicks from the 900 and 300 µm treatments of each grain source were sacrificed for evaluation of the gastrointestinal tract.

Results and Discussion

Measurements of milling characteristics are given in Table 2. When averaged across all particle sizes, corn required over twice as much electrical energy to mill as the sorghums. This difference was greatest for grain ground to 500 µm through the roller mill, where corn required nearly four times as much energy to grind compared to the sorghums (e.g., 14.3 kwh/ton vs 3.7 kwh/ton). It is interesting to note that both sorghums could be ground to 500 µm with less electrical energy than that required to grind corn to 900 µm. Production rates for the sorghums vs corn also favored milling the sorghums to 500 µm vs milling corn to 900 µm.

Hard sorghum required slightly less energy to roller mill than soft sorghum at particle sizes of 900, 700 and 500 µm, but hard sorghum required more energy to hammermill to 300 µm than soft sorghum. Energy required to pellet was similar between grain sources with small improvements as particle size was reduced to 500 µm. Likewise, pellet durability was not different for the cereal grains, but there was a trend for slight decreases in durability as particle size was reduced from 900 to 500 µm.

Growth data for the weanling pigs are given in Table 3. For d 0 to 7, as particle size was reduced from 900 to 300 µm, ADG and F/G were improved for pigs fed all grain sources, with the greatest positive response in pigs fed corn. At 300 µm, pigs fed hard sorghum were 4% more efficient than pigs fed corn, but had 7% lower ADG. Pigs fed soft sorghum had 7 and 8% poorer ADG and F/G than pigs fed corn milled to 300 µm.

For d 0 to 14, pigs fed sorghum ground to 900 µm had greater ADG than pigs fed corn ground to 900 µm, but at 300 µm, pigs fed corn had 8 and 15% greater ADG than pigs fed hard and soft sorghum, respectively. Optimum particle sizes for F/G were 500 µm for corn and soft sorghum and 300 µm for hard sorghum. At these optimum particle sizes, the feeding values of hard and soft sorghum, relative to corn, were 94 and 93%, respectively.

For d 0 to 35, pigs fed diets containing corn gained 23% faster, consumed 16% more feed, and were 6% more efficient than pigs fed the sorghums. Optimum particle size for F/G was 500 µm for all grain sources, with ADG for pigs fed hard and soft sorghum at 80 and 84% that of corn, respectively, and efficiency of gain at 96% that of corn for both sorghums.

Stomachs from pigs sacrificed at the end of the growth assay were subjectively scored for lesions of the epithelium in the upper esophageal region. No ulcers were found, but there were differences in the epithelial surface. For corn and hard sorghum, pigs fed the 300 µm treatment had greater keratinization than pigs fed the 900 µm treatment. In contrast, pigs fed soft sorghum had less keratinization when fed the 300 µm treatment versus the 900 µm treatment. These data casts doubt on the significance of fine-grinding as a cause of stomach ulcers in nursery-age pigs.

Growth performance and intestinal tract morphology data from the chick assay are given in Table 4. For d 0 to 7, chicks fed sorghum at 900 µm had poorer gains and F/G than chicks fed corn at 900 µm. However, when compared at the optimum particle size for each grain (300 µm for corn, 500 µm for hard sorghum and 300 µm for soft sorghum) the hard and soft sorghums supported gain and F/G that were 108 and 99% that of corn.

For d 0 to 21, chicks fed corn were more efficient than chicks fed the sorghums, but that response was affected by particle size. At 900 µm, chicks fed corn had 11% greater ADG and were 5% more efficient than chicks fed sorghum, but at the optimum particle size for each grain source, chicks fed sorghum gained 3% more weight and were 99% as efficient as chicks fed corn. This was because of less response to particle size reduction in corn than sorghum. Maximum gain was achieved at 700 µm and maximum efficiency of gain was achieved at 300 µm for corn and hard sorghum. Maximum gain and efficiency of gain was achieved at 500 µm for soft sorghum.

Gizzard weights were reduced by 14, 21 and 29% for corn, hard sorghum and soft sorghum, respectively, when the grains were milled to 300 µm versus 900 µm. Proventriculus weights were reduced 1, 23 and 21% for chicks fed corn, hard and soft sorghum milled to 300 µm versus 900 µm. There is currently a great deal of interest in the energy required to maintain the gastrointestinal tract and liver of livestock; energy that could have been used for growth of lean tissue. It is possible that these differences in organ weights are contributing to improved feed efficiency of chicks fed grains milled to small particle sizes.

Gizzards were subjectively scored on a scale of 1 to 3, with 1=normal appearance, 2=moderate abrasions and 3=severe abrasions and(or) erosions. Chicks fed corn ground to 300 µm had higher scores than those fed corn ground to 900 µm, but the reverse was true for chicks fed the sorghums.

In conclusion, production rate slowed and energy requirements increased as particle size was decreased. However, the sorghums required less energy to grind and had greater production rates compared to corn. There were improvements in F/G in both starter pigs and broiler chicks as particle size was reduced. This reached an optimum at 300 to 500 µm for both species, and was somewhat dependent on grain source and age of the animals. It should be noted that differences in utilization (especially ADG) of sorghum versus corn were greater in nursery pigs compared to broiler chicks. Considering energy required for milling, production rate, and growth performance, milling sorghum and corn to 500 µm is recommended in pelleted diets for newly weaned pigs; a response that corresponds quite well with the chick data. However, even though growth performance was improved for weanling pigs as particle size was decreased, fine-grinding has been associated with stomach ulcers in finishing pigs. Microscopic evaluations of the intestinal tracts of the pigs and chicks are in progress and will be used to ensure that well-being of the animals was not compromised by fine-grinding of the cereal grains.

Table 1. Composition of Basal Diets[a]

	Nursery pigs		
Ingredient	Phase 1	Phase 2	Broilers
Corn[b]	40.24	58.54	54.42
Soybean meal (48%)	32.40	29.30	39.30
Soy oil	3.00	2.00	1.00
Whey	20.00	5.00	—
Vit/Min/Antibiotic[c]	4.26	4.81	4.93
Lysine-HCl	.10	.10	—
DL-methionine	—	—	.25
Chromic oxide	—	.25	.10

[a]Diets were formulated to contain 1.25 lysine, .9% Ca, and .8% P in Phase I and 1.15% lysine, .8% Ca, and .7% P in Phase II. Broiler diets were formulated to contain 23% CP, 1.1% Ca, and 1.0% P.
[b]Hard and soft sorghums replaced corn on an lb per lb basis.
[c]KSU vitamin, mineral and selenium premixes, monocalcium phosphate, limestone, and .3% salt. Antibiotic supplied 100 g/ton chlortetracyine, 100 g/ton sulfathiazole, 50 g/ton penicillin, and 250 ppm Cu in the pig diets, and 100 g/ton chlortetracycline and .05% amprolium in the broiler diets.

Table 2. Effects of Grain Source on Milling Characteristics and Pellet Durability

	Corn				Hard sorghum				Soft sorghum			
	900	700	500	300	900	700	500	300	900	700	500	300
Particle size, µm	919	702	487	369	902	741	512	345	888	715	497	341
Variation in particle size (Sgw)	1.92	1.86	1.65	1.69	2.1	2.03	1.90	1.60	2.02	1.83	1.82	1.66
Grinding energy, kwh/ton	4.8	8.4	14.3	22.2	1.5	2.1	3.4	18.2	1.7	2.3	3.9	13.9
Production rate, ton/h	1.9	1.1	.7	.7	6.6	4.5	2.6	.8	4.9	3.8	2.1	1.3
Pelleting energy (Phase 1), kwh/ton	27.4	26.3	26.4	26.5	28.5	28.7	27.0	27.6	27.9	27.8	27.7	29.1
Pelleting energy (Phase 2), kwh/ton	34.8	34.0	33.0	33.3	34.2	26.7	33.8	34.3	36.6	35.4	31.9	34.0
Pellet durability (Phase 1), %	97.3	95.3	95.3	96.0	96.0	95.3	94.7	97.3	95.3	95.3	95.3	96.0
Pellet durability (Phase 2), %	91.4	90.0	89.7	90.8	90.9	88.8	84.9	86.2	88.6	91.5	87.1	91.2
Fines (Phase 1), %	3.5	3.6	3.8	3.8	3.5	2.9	3.1	2.9	3.8	3.1	3.0	3.8
Fines (Phase 2), %	7.6	6.5	6.0	5.6	8.8	7.1	7.9	6.5	9.1	7.4	6.8	5.5.5

Table 3. Effect of Grain Type and Particle Size on Growth Performance and Stomach Lesions in Starter Pigs[a]

	Corn				Hard sorghum				Soft sorghum				
	900	700	500	300	900	700	500	300	900	700	500	300	CV
d 0 to 7													
ADG, lb[ei]	.44	.49	.50	.59	.54	.53	.52	.55	.49	.49	.48	.55	15.1
ADFI, lb[l]	.54	.57	.52	.55	.52	.57	.54	.49	.56	.52	.50	.57	12.7
F/G[fj]	1.23	1.16	1.04	.93	.96	1.08	1.04	.89	1.14	1.06	1.04	1.04	11.1
d 0 to 14													
ADG, lb[fgj]	.61	.64	.73	.77	.67	.62	.66	.71	.67	.60	.63	.67	10.9
ADFI, lb[m]	.76	.79	.78	.83	.82	.76	.77	.80	.80	.73	.72	.79	11.2
F/G[fi]	1.25	1.23	1.06	1.07	1.22	1.23	1.18	1.13	1.20	1.23	1.14	1.17	7.7
d 0 to 35													
ADG, lb[b]	.94	.90	.96	.93	.76	.73	.77	.67	.81	.77	.81	.74	11.3
ADFI, lb[bd]	1.41	1.31	1.36	1.33	1.19	1.13	1.14	1.09	1.28	1.18	1.20	1.14	10.0
F/G[bh]	1.50	1.46	1.42	1.43	1.57	1.55	1.48	1.63	1.58	1.53	1.48	1.54	4.9
Stomach score[cekn]	1.00	—	—	1.75	1.20	—	—	2.00	1.35	—	—	1.05	35.3

[a]240 pigs, 5 pigs/pen, 4 pens/treatment (avg initial wt of 11.7 lb).
[b]Corn vs sorghums (P<.001).
[c]Hard vs soft (P<.10).
[def]Particle size linear (P<.10, P<.05, P<.01, respectively).
[gh]Particle size quadratic (P<.10, P<.05, respectively).
[ij]Corn vs sorghums x particle size linear (P<.10, P<.05, respectively).
[k]Hard vs soft × particle size linear (P<.05).
[l]Hard vs soft × particle size quadratic (P<.05).
[m]No treatment effect (P>.10).
[n]1=normal, 2=moderate keratinization, 3=severe keratinization.

Table 4. Effect of Grain Type and Particle Size on Growth Performance Organ Weights and Gizzard Lesions in Broiler Chicks[a]

	Corn				Hard sorghum				Soft sorghum				
	900	700	500	300	900	700	500	300	900	700	500	300	CV
d 0 to 7													
Gain, lb[fin]	.24	.26	.27	.26	.21	.29	.28	.27	.23	.26	.27	.28	15.5
Feed intake, lb[h]	.36	.37	.36	.34	.33	.39	.37	.36	.36	.37	.36	.37	10.9
F/G[gjm]	1.50	1.42	1.33	1.31	1.57	1.34	1.32	1.33	1.57	1.42	1.33	1.32	7.7
d 0 to 21													
Gain, lb[ejl]	1.61	1.62	1.61	1.57	1.43	1.66	1.64	1.62	1.47	1.59	1.66	1.62	7.9
Feed intake, lb[il]	2.43	2.43	2.38	2.32	2.26	2.57	2.46	2.41	2.35	2.43	2.47	2.47	6.6
F/G[bdgio]	1.51	1.50	1.48	1.48	1.58	1.55	1.50	1.49	1.60	1.53	1.49	1.52	2.9
Gizzard wt, g/kg[cgk]	24.4	—	—	20.9	23.5	—	—	18.5	24.5	—	—	17.5	15.6
Proventriculus													
wt, g/kg[gl]	5.03	—	—	4.98	5.38	—	—	4.16	5.20	—	—	4.14	20.3
Gizzard score[lp]	1.27	—	—	2.00	1.92	—	—	1.76	1.71	—	—	1.60	34.8

[a]420 chicks, 5 chicks/cage, 7 cages/treatment (avg initial wt of .15 lb).
[bc]Corn vs sorghums (P<.10, P<.05, respectively).
[d]Hard sorghum vs soft sorghum (P<.001).
[efg]Particle size linear (P<.05, P<.01, P<.001, respectively).
[hij]Particle size quadratic (P<.12, P<.05, P<.01, respectively).
[kl]Corn vs sorghums x particle size linear (P<.10, P<.05, respectively).
[m]Corn vs sorghums x particle size quadratic (P<.10).
[no]Hard sorghum vs soft sorghum × particle size quadratic (P<.10, P<.05, respectively).
[p]1=normal, 2=moderate abrasion, 3=severe abrasion and/or erosion.

EFFECTS OF A GRIND & MIX HIGH NUTRIENT DENSITY DIET ON STARTER PIG PERFORMANCE

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Summary

Two 4-wk growth trials utilizing 520, 21-d old weanling pigs (22 ± 2 d and 13.7 lb) were conducted to evaluate either grind & mix (meal form) or pelleted high nutrient density diets on growth performance. One half of the pigs were fed a standard (20% dried whey and 10% plasma protein) high nutrient density diet (HNDD1) either in a pelleted or meal form. The other half received a high nutrient density diet (HNDD2; either pelleted or meal form) formulated with ingredients having greater flowability characteristics in order to determine if pelleting is necessary for pigs fed high nutrient density diets. Each trial was split into two identical phases, with Phase I being d 0 to 9 postweaning and Phase II being d 9 to 28 postweaning. Experimental diets were formulated to 1.5% lysine, .90% calcium, and .80% phosphorus and were fed only during Phase I. All pigs were fed a common diet (meal form) during Phase II formulated to 1.25% lysine containing 10% dried whey and 5% fish meal. There was an interaction between diet form and diet composition for ADG during Phase I (0-9 d) postweaning. Pigs fed meal-form HNDD1 had a slightly higher ADG compared to pigs fed the same diet in a pelleted form. However, pigs fed pelleted HNDD2 grew slightly faster than pigs fed the meal-form of the same diet during Phase I. There were no interactions between diet form and composition for F/G or ADFI during Phase I or during the overall experiment. At d 9 postweaning, there was no difference in F/G between pigs fed HNDD1 or HNDD2. However, pigs fed pelleted diets were more efficient than meal-fed pigs. Overall (d 0 to 28), pigs fed pelleted diets during Phase I, regardless of composition, were more efficient than pigs fed meal diets. Based on the results on this experiment, a high nutrient density diet can be fed in either a meal or pelleted form. Feed efficiency was 20% poorer for pigs fed the HNDD in the meal form. Therefore, a pelleted HNDD can cost up to 120% (excluding bagging expense) of mixing the same diet on-farm and be cost effective. Additional research is needed to understand the interaction between diet form and composition for ADG during Phase I and to improve diet flowability.

(Key Words: Starter, Performance, Process, Diet, Density.)

Introduction

Important research breakthroughs in nutritional programs for the early-weaned pig have occurred in the last decade. Introductions of the high nutrient density diet (HNDD) and three-phase starter program have provided a management method of economically eliminating the postweaning lag often found when feeding simple corn-soybean meal diets to young pigs. Recent research has demonstrated that the HNDD starter diet is not only necessary to optimize growth performance in the nursery, but also to maximize subsequent performance in the grower and finisher phases. This diet has traditionally been high in milk products and necessitated pelleting for flowability, which resulted in increased cost. With new ingredients (i.e., porcine plasma protein) used to formulate the HNDD diet, the potential to on-farm mix the Phase I diet needs to be evaluated. Thus, the objective of this experiment is to evaluate the effects of two diets formulated from ingredients of known differences in flowability fed in two physical forms (pelleted or meal) on early weaned pig growth performance.

Procedures

This experiment was conducted in two identical 4-wk growth trials. A total of 520 21-d old weanling pigs (avg initial wt=13.7 lb) was used to evaluate two diets formulated from ingredients of known differences in flowability fed in two physical forms (pellets or meal). The four experimental treatments were in a 2 × 2 factorial arrangement consisting of two high nutrient density diets (HNDD1 or HNDD2) fed in a meal or a pelleted form. The HNDD2 diet was formulated with ingredients to help eliminate feeder bridging problems. Each trial was split into two phases, with Phase I from d 0 to 9 postweaning and Phase II from d 9 to 28 postweaning. Experimental diets were fed only during Phase I. All pigs were fed a common diet (meal form) during Phase II. Pigs were housed 13 per pen (10 pens per treatment) in 4 ft × 8 ft pens in an environmentally controlled nursery with woven wire flooring and allowed ad libitum access to feed and water. Pigs were weighed, and feed consumption was determined on d 9 and 28 to determine ADG, ADFI, and F/G.

Two experimental diets were used during Phase I (Table 1). These diets were fed in either a meal or pellet form. Diets were formulated to 1.5% lysine, .9% calcium, and .8% phosphorus. The first diet, HNDD1 was a standard Phase I diet containing 10% spray-dried porcine plasma protein, 10% lactose, and 20% edible grade dried whey. Because of anticipated flowability problems, HNDD2 was formulated with only 10% dried whey. Soybean meal was replaced with extruded soy protein concentrate in this diet in an attempt to improve growth performance in a diet with a lowered dried whey content. The Phase II diet contained 1.25% lysine, 10% dried whey, and 5% fish meal.

Results and Discussion

There was an interaction ($P<.05$) between diet form and diet composition for ADG during Phase I (0 to 9 d) postweaning (Table 2). Pigs fed HNDD1 in the meal form had a slightly higher ADG compared to pigs fed the same diet in a pelleted form. However, pigs fed HNDD2 in the pelleted form grew slightly faster than pigs fed the same diet in the meal form during Phase I. The second HNDD was formulated from ingredients that had an improved flowability compared to HNDD1, yet pigs could have wasted more of HNDD2 fed in the meal form. The feeders used in this experiment did not have agitators. The meal diets had noticeably poorer flowability than the pelleted diets. Also, pigs fed HNDD1 in the pelleted form had a numerically lower ADFI compared to pigs fed any other dietary treatment, which could possibly be related to pelleting conditions and less wastage. Additional experiments are needed to fully understand this interaction.

There were no interactions ($P>.18$) between dietary form and composition for F/G or ADFI during Phase I or during the overall experiment. At 9 d postweaning, there was no difference in F/G between pigs fed HNDD1 or HNDD2. However, pigs fed pelleted diets were more efficient ($P<.01$) than pigs fed diets in meal form. These differences in feed efficiency are in agreement with several experiments showing that feed wastage is higher in diets fed in the meal form, resulting in a poorer efficiency compared to pellets.

During Phase II (9-28 d), there were no differences in ADG, ADFI, or F/G among dietary treatments. Because all pigs were fed the same diet in the meal form, similar growth performance is not surprising. Overall (d 0 to 28), there was a tendency ($P<.08$) for an interaction between diet form and diet composition for ADG. This interaction was caused by the previously discussed interaction during Phase I of the experiment. Diet composition had no effect on ADFI or F/G. Pigs fed pelleted diets during Phase I, regardless of composition, were more ($P<.01$) efficient than pigs fed meal diets.

Based on the results of this experiment, a high nutrient density diet can be fed in either a meal or pelleted form. Before feeding the

HNDD in the meal form, producers must realize that decreased flowability results in increased feeder management. Feed efficiency was 20% poorer for pigs fed the HNDD in the meal form. Therefore, a pelleted HNDD can cost up to 120% the cost of mixing the same diet on the farm and still be cost effective. Additional research is needed to understand the interaction between diet form and composition for ADG in Phase I and to improve diet flowability.

Table 1. Composition of Diets, %

Ingredient	HNDD1[a]	HNDD2[a]	Phase II
Corn	32.6	45.8	—
Milo	—	—	54.1
Extruded soy protein concentrate	—	16.2	—
Soybean meal (44% CP)	19.3	—	—
Soybean meal (48% CP)	—	—	19.6
Dried whey	20.0	10.0	15.0
Lactose	10.0	10.0	—
Fish meal	—	—	5.0
Porcine plasma protein	10.3	10.0	—
Soybean oil	3.0	3.0	3.0
Monocalcium phoshate (21% P, 18.5% Ca)	2.5	2.6	1.3
Limestone	.7	.9	.4
Salt	—	—	.2
Lysine	—	—	.2
D1-methionine, 99%	.8	.7	—
Vit/trace min/antibiotic	.7	.7	1.1
Copper sulfate	.1	.1	.1
Total	100.0	100.0	100.0

[a]HNDD1=high nutrient density diet one; HNDD2=high nutrient density diet two.

Table 2. Effect of Physical Form (Meal or Pellet) of a HNDD on Growth Performance in Starter Pigs[a]

	HNDD1[b]		HNDD2[b]		
Item	Pellet	Meal	Pellet	Meal	CV
<u>0-9 d</u>					
ADG, lb[c]	.46	.49	.50	.45	12.6
ADFI, lb[d]	.50	.63	.53	.59	13.3
F/G[d]	1.08	1.27	1.08	1.31	9.9
<u>9-28 d</u>					
ADG, lb	.70	.73	.74	.73	9.0
ADFI, lb	1.19	1.24	1.22	1.23	6.0
F/G	1.70	1.71	1.65	1.70	5.9
<u>0-28 d</u>					
ADG, lb[e]	.62	.65	.67	.64	9.0
ADFI, lb[e]	.96	1.05	1.01	1.02	7.3
F/G[d]	1.55	1.62	1.50	1.59	4.3

[a]A total of 520 pigs, 13 pigs/pen, 10 pens/treatment.
[b]HNDD1 = High nutrient density diet one; HNDD2 = High nutrient density diet two.
[c]Interaction of diet form × diet composition ($P<.05$).
[d]Main effect of meal vs pellet ($P<.01$).
[e]Interaction of diet form × diet composition ($P<.08$).

EVALUATION OF EXPELLED SOYBEAN MEAL IN STARTER DIETS

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Summary

Forty-eight weanling pigs (6.9 lb initial wt) were used in a 28-d growth study to determine the feeding value of expelled soybean meal (43% CP) as compared to conventionally extracted soybean meal (48.5% CP). Pigs were fed one of two dietary treatments containing either expelled soybean meal or conventional soybean meal. Both diets contained milo and 10% dried whey and were formulated to be slightly lysine deficient (.95%) to determine any potential differences in amino acid availabilities between the two soybean meals. From d 0 to 14, pigs fed conventional soybean meal had higher average daily gain (ADG) and average daily feed intake (ADFI) and were more efficient (F/G; 26.2%, 11.3%, and 21.6%, respectively) than pigs fed expelled soybean meal. Similar trends were noted for the overall experiment (d 0 to 28) with pigs fed conventionally extracted meal having greater ADG (16.1%) and ADFI (8.8%) and better F/G (6.2%) than pigs fed the expelled soybean meal. Both soybean meal products were analyzed for percentage fat; the expelled meal contained 6.2% and conventional meal contained .83%. The added fat in the expeller meal did not improve F/G compared to the conventional soybean meal. Protein solubility in both expelled and conventionally extracted soybean meal was greater than 70%, thus neither meal was overprocessed. However, trypsin inhibitor activity was higher in the expelled soybean meal (3.4 mg/g) as compared to the conventional soybean meal (.5 mg/g). This difference may be responsible for the poorer ADG, ADFI, and F/G found when feeding the expelled soybean meal. Based on this research, expelled soybean meal has approximately 84% the feeding value of conventionally extracted soybean meal when formulated on a lysine basis.

(Key Words: Starter, Performance, SBM, Process, Soybean.)

Introduction

Prior to solvent extraction, soybeans were processed by expeller procedures to remove the oil. Today solvent extraction is the most common method of extracting soybean oil; however, the expeller process is still being used in some areas. In the expeller process, the soybeans are cracked, dried, and transported to a tempering device, which stirs the soybeans for uniform heat processing. The soybeans are then fed into an expeller barrel, which presses the oil from the beans. The soybeans leave the barrel and are ground. The expeller process leaves the beans with approximately 5% fat. In solvent extraction, the beans are cracked and then heated to 140
Soybeans are then allowed to cool to 113
beans are then hexane extracted, volatilized, and dried. From the dryer, the beans are conveyed to a toaster, cooled, and ground, leaving them with less than 1% fat. Expeller meal is higher in fat content, which could add to its feeding value. Therefore, this experiment was designed to determine the feeding value of the expelled soybean meal in starter diets compared to conventionally extracted soybean meal.

Procedures

The expelled and conventional soybean meals were analyzed for percentage protein and diets were then formulated (Table 1) to .95% lysine. Lysine was assumed to be a fixed percentage of protein in the two soybean meals. Lysine was set to be slightly deficient to ensure that differences in protein quality could be detected. Light pigs (6.9 lb) were used in the study to further stress the need for lysine availability in the two soybean meals. Only 10% dried whey was added to the diet to minimize the confounding effects of other protein sources.

Forty-eight weanling pigs (6.9 lb initial wt) were fed the dietary treatments for the 28 d study. The pigs were blocked by weight and allotted by ancestry and gender to pens (six per pen and four pens per treatment) in an environmentally controlled nursery equipped with elevated pens. Each pen had a self-feeder and nipple waterer, so feed and water could be consumed ad libitum. The pigs and feeders were weighed weekly to calculate performance data (ADG, ADFI, and F/G). Feed and soybean meal samples were collected and analyzed for percentage CP, dry matter, fat, protein solubility , trypsin inhibitor activity and urease activity (Table 2).

Results and Discussion

Pigs fed conventional soybean meal from d 0 to 14 had increased ADG (26.2%, P<.05) and improved F/G (21.6%, P<.07) compared to pigs fed expelled soybean meal. Also seen was an increased ADFI (11.3%) for the pigs fed conventionally extracted soybean meal, although this was not a significant increase. Similar responses were noted for the overall experiment (d 0 to 28), though the differences were not as pronounced, with pigs fed conventional soybean meal showing a 16% increase in ADG (P<.05) compared to those fed expelled soybean meal. Pigs fed the conventional soybean meal tended to have improved ADFI and F/G (8.8% and 6.3%, respectively) compared to those fed the expelled soybean meal. Protein solubility values are indicators of overprocessing. Any value less than 70% indicates the sample is overcooked. However, both the expelled soybean meal (82.8%) and the conventional soybean meal (82.7%) are well above 70% and, therefore, not overprocessed. The trypsin inhibitor activity assay, which measures amount of trypsin inhibitor in soybean meal samples, revealed that the expelled soybean meal contained more trypsin inhibitor (3.40 mg/g) than conventional soybean meal (.5 mg/g), with less than 2 mg/g being optimum. This difference may have contributed to the poorer ADG, ADFI, and F/G, seen in the pigs fed the expelled soybean meal. Urease activity was determined, to check for underprocessing in the two soybean meals (the optimum range being .02 to .2). Expelled soybean meal (.037) was slightly higher than conventional soybean meal (.017). However, based on urease activity, neither soybean meal was underprocessed, contradicting the trypsin inhibitor activity values. The percentage fat was determined; the expelled soybean meal contained 6.29%, whereas the conventional soybean meal contained only .82%. However, when the diets were formulated, the expeller meal diet contained 1.5% fat, whereas the conventional soybean meal diet contained .83% fat. This .7% higher fat content in the expeller meal diet had no apparent effect on ADG, ADFI, or F/G. Although expelled soybean meal appears to be a poorer protein source (approximately 84% of the feeding value of conventional soybean meal) for starter pig diets, future studies may be needed to further evaluate its feeding value.

Table 1. Diet Composition

Ingredient %	Conventional Soybean Meal Diet	Expelled Soybean Meal Diet
Conventional SBM	22.44	---
Expelled SBM	---	25.16
Milo	62.84	60.06
Dried whey	10.00	10.00
Monocalcium phosphate	1.93	1.87
Antibiotic	1.00	1.00
Limestone	.86	.99
Salt	.40	.40
Vitamin premix	.25	.25
Trace mineral mix	.15	.15
Copper sulfate	.08	.08
Selenium premix	.05	.05
Total	100.00	100.00

Table 2. Chemical Analysis

	Conventional SBM	Conventional SBM Diet	Expelled SBM	Expelled SBM Diet
Crude protein, %	49.56	18.99	43.25	17.54
Dry matter, %	89.90	90.15	90.90	90.75
Crude fat, %	.82	.83	6.29	1.53
Trypsin inhibitor activity, mg/g	.50		3.40	
Protein solubility, %	82.70		82.82	
Urease activity, pH	.02		.04	

Table 3. Performance of Nursery Pigs Fed Conventional Soybean Meal or Expelled Soybean Meal[a]

	Conventional Soybean Meal Diet	Expelled Soybean Meal Diet
d 0 to 14		
ADG, lb[b]	.42	.31
ADFI, lb	.62	.55
F/G[c]	1.48	1.78
d 0 to 28		
ADG, lb[b]	.56	.47
ADFI, lb	1.14	1.04
F/G	2.05	2.18

[a]A total of 48 pigs, 6.9 lb avg initial wt, 23.7 lb avg final wt, 28 d trial.
[b](P<.05).
[c](P<.07).

EFFECTS OF PELLETING LOW-LYSINE DIETS WITH FERMENTATION PRODUCTS FOR WEANLING PIGS

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Summary

One hundred twenty pigs (13.2 lb avg initial wt) were used in an experiment to determine the effects of pelleting on the ability of fermentation products to improve growth performance of nursery-age pigs fed low-lysine diets. Treatments were: 1) positive control (1.15 and .95% lysine for d 0 to 14 and 14 to 35, respectively); 2) diet 1 pelleted; 3) low-lysine regimen (1.05 and .85% lysine for d 0 to 14 and 14 to 35, respectively) supplemented with fermentation product (FP)[1]; 4) diet 3 pelleted; 5) low-lysine regimen supplemented with modified fermentation product (MFP)[2]; and 6) diet 5 pelleted. For pelleting, the diets were pre-conditioned to 131°F and pelleted (5/32" diameter pellets) at an avg production rate of 3,550 lb/h, with an avg exit temperature of 144°F. The pigs were allowed to consume feed and water ad libitum during the 35-d experiment. For d 0 to 7 and 0 to 14, pigs fed the pelleted diets had greater ADG and efficiency of gain than pigs fed diets in meal form. At d 14, apparent digestibilities of DM and N of the control diet were increased by pelleting, but those of the diets with fermentation products added were not affected. CFUs of lactobacilli, streptococci, and coliforms in feces were not affected by treatment. From d 14 to 35, pigs fed pelleted diets were more efficient but consumed less feed and had lower ADG than pigs fed diets in meal form. For d 0 to 35, ADG was not affected by treatment, but pigs fed pelleted diets consumed 8% less feed and had 8% greater efficiencies of gain than pigs fed diets in meal form. Growth performance of pigs fed the low-lysine diets plus the fermentation products was not different than that of pigs fed diets with adequate lysine concentrations. Performance of pigs fed FP or MFP was not different. At d 35, CFUs of lactobacilli in feces were not affected by treatment. CFUs of streptococci were greater for pigs fed the control diet than for pigs fed the treatment diets, but were decreased by pelleting the control diet, whereas pelleting the treatment diets increased CFUs of streptococci in feces. CFUs of coliforms were greater for pigs fed diets with MFP than those fed diets with FP. In conclusion, growth performance of pigs fed low-lysine diets plus fermentation products was equal to that of pigs fed diets with adequate lysine concentrations.

(Key Words: Lysine, Probiotic, Starter, Digestibility, Performance, Fecal Microbes.)

Introduction

Use of fermentation products to spare protein (lysine) could allow nutritionists to formulate low-protein diets that are advantageous from economical and environmental standpoints. Previous research at this station (see 1990 KSU Swine Day Report, page 79) indicated that nursery diets with 17% crude protein and 1.25 lb/ton of FP supported growth performance equal to a 19% crude protein control diet. However, feeding FP at concentrations greater than 1.25 lb/ton was of no benefit to nursery pigs and actually depressed feed intake and rate of gain in growing and finishing pigs. The experiment reported herein was designed to confirm the performance

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[1]Fermentation product was Fermacto®, Pet-Ag, Inc., Elgin, IL 60120.

[2]Modified fermentation product was Modified Fermacto, Pet-Ag, Inc., Elgin, IL 60120.

enhancement from inclusion of 1.25 lb/ton of FP in low-lysine nursery diets, and to determine if modification of FP would improve diet palatability and feed intake. Also, the efect of pelleting on any growth-promoting effect of the fermentation products was evaluated.

Procedures

One hundred twenty pigs (13.2 lb avg initial wt) were allotted to six treatments based on ancestry, sex, and weight. The pigs were housed (four pigs/pen and five pens/treatment) in an environmentally controlled nursery equipped with a woven-wire floor. Each pen had a self-feeder and nipple waterer so feed and water could be consumed ad libitum. At weaning (21 d of age), the pigs were given the Phase I diet (Table 1) from d 0 to 14 of the experiment and the Phase II diet from d 14 to 35 of the experiment. The diet ingredients were analyzed for lysine concentration and blended to give the following treatments: 1) positive control (1.15 and .95% lysine for d 0 to 14 and 14 to 35, respectively); 2) diet 1 pelleted; 3) low-lysine regimen (1.05 and .85% lysine for d 0 to 14 and 14 to 35, respectively) supplemented with FP; 4) diet 3 pelleted; 5) low-lysine regimen supplemented with MFP; and 6) diet 5 pelleted. For pelleting, the diets were preconditioned to 131°F and pelleted (5/32" diameter pellets) at an avg production rate of 3,550 lb/h, with an avg exit temperature of 144°F. All feed additions were recorded, and pig and feeder weights were collected weekly. On d 14 and 35 of the experiment, fecal samples were collected from one pig in each pen by rectal massage for determination of colony forming units (CFUs) of lactobacilli (Bacto Lactobacilli MRS broth), streptococci (Slanetz and Bartley medium), coliforms (violet-red bile agar), and total bacteria (plate count agar). Additionally on d 14, fecal samples were collected from all pigs, pooled within pen, and analyzed for DM, N, and Cr concentrations. Apparent digestibilities of DM and N were calculated using the indirect ratio method. Response criteria were ADG; ADFI; F/G; apparent digestibilities of DM and N; percentage fecal moisture; and CFUs of lactobacilli, streptococci, and coliforms in the feces. Orthogonal contrasts were used to compare meal versus pelleted diets, control versus low-lysine diets with fermentation products, FP versus MFP, and all appropriate interaction effects. Total CFUs of fecal bacteria (plate count agar) were used as covariates in the statistical analyses of CFUs of fecal microbes.

Results and Discussion

Samples were evaluated pre- and postpelleting to ensure that pelleting conditions were uniform for all diets. Production rates ranged from 3,464 to 3,599 lb/h, conditioning temperature was constant at 131°F, and exit temperature ranged from 142 to 145°F, so pelleting conditions were quite consistent.

Results from the growth assay are given in Table 2. For d 0 to 7, ADFI was not affected by treatment, but improvements were observed for ADG and F/G when the diets were pelleted. For d 0 to 14, ADG was improved by 16% and F/G was improved by 15% when the diets were pelleted. There were no interactions between pelleting the diets and inclusion of fermentation products for growth performance to d 14. Performance of pigs fed the low-lysine diets supplemented with fermentation products was not different than that of pigs fed diets with adequate lysine concentrations, and there were no differences in performance for pigs fed FP versus MFP. So, the fermentation products appeared to support normal growth performance in pigs fed the low-lysine diets, but either product was equally effective during d 0 to 14 of the experiment. Digestibility of DM was increased by 3% when the control diet was pelleted but was not affected when the treatment diets were pelleted. Digestibility of N was greater for pelleted diets versus meal diets, although this response was more pronounced in the control diet versus the diets with fermentation products. Diets with MFP had greater digestibility of N than diets with FP. Bacterial concentrations in the feces (i.e., CFUs of lactobacilli, streptococci, and coliforms) were not affected by treatment at d 14.

For d 14 to 35, F/G was improved by pelleting the diets, but ADFI was decreased by 11%, to the point that ADG was reduced by 6%. However, for the overall experiment (d 0 to 35), ADG was not affected by pelleting, with an 8% reduction in ADFI and an 8% improvement in F/G. There were no interactions for growth performance between pelleting the diets and inclusion of fermentation products for d 14 to 35 or 0 to 35. CFUs of lactobacilli in feces were not affected by treatment. Streptococci concentration was greater in control pigs than pigs fed the fermentation products and was decreased when the control diet was pelleted but increased when the diets with fermentation products were pelleted. Pigs fed diets with MFP had more CFUs of coliform in their feces than pigs fed FP, with pigs fed the control diets being intermediate.

In conclusion, pelleting nursery diets improved ADG and F/G for the first 2 wk postweaning and F/G for the last 3 wk of the experiment. However, depressed ADFI for pigs fed the pelleted diets during the last 3 wk of the experiment resulted in reduced ADG. Low-lysine diets with fermentation products and diets with adequate lysine supported equal growth performance, and pelleting did not affect growth performance of pigs fed the low-lysine diets differently than pigs fed the control diets.

Table 1. Composition of Diets, %[ab]

	Phase I		Phase II	
Ingredient	Control (1.15% lys)	Low-lysine (1.05% lys)	Control (.95% lys)	Low-lysine (.85% lys)
Corn	48.41	48.54	64.41	64.54
Soybean meal (48% CP)	19.65	19.65	20.75	20.75
Whey	20.00	20.00	5.00	5.00
Select menhaden fishmeal	3.00	3.00	—	—
Lysine-HCl	.13	—	.13	—
Choice white grease	5.00	5.00	5.00	5.00
Vitamins and minerals	2.21	2.21	3.36	3.36
Antibiotics[c]	1.10	1.10	1.10	1.10
Chromic oxide	.25	.25	—	—
Treatment premix[d]	.25	.25	.25	.25

[a]Diets were formulated to supply .9% Ca, and .8% P in all diets, 3.22 and 2.65 g lys/Mcal DE for the Phase I and II control diets, and 2.93 and 2.37 g lys/Mcal DE for the Phase I and II treatment diets.
[b]The diets were fed in meal and pellet form.
[c]Supplied per ton of diet: 100 g chlortetracycline; 100 g sulfathiazole; 50 g penicillin; 250 ppm Cu.
[d]The treatment premix was finely ground corn for the control diets and supplied either 1.25 lb/ton of FP or 2.25 lb/ton of MFP for the treatment diets.

Table 2. Growth Response of Pigs Fed Low-lysine Diets Supplemented with Fermentation Products[a]

	1.15/.95% lysine control diet		1.05/.85% lysine + FP		1.05/.85% lysine + MFP		
Item	Meal	Pellet	Meal	Pellet	Meal	Pellet	CV
d 0-7							
ADG, lb[d]	.49	.60	.53	.57	.52	.66	21.6
ADFI, lb[b]	.67	.71	.66	.63	.65	.79	19.0
F/G[d]	1.41	1.20	1.28	1.12	1.27	1.18	15.2
d 0-14							
ADG, lb[d]	.61	.74	.68	.71	.60	.75	16.3
ADFI, lb[b]	.93	.91	.93	.86	.88	.96	12.7
F/G[f]	1.55	1.24	1.39	1.22	1.46	1.29	10.7
d 14-35							
ADG, lb[c]	1.18	1.18	1.21	1.06	1.15	1.10	8.4
ADFI, lb[e]	2.13	2.02	2.25	1.87	2.09	1.90	9.5
F/G[e]	1.79	1.72	1.85	1.76	1.83	1.73	4.4
d 0-35							
ADG, lb[b]	.96	1.00	1.00	.92	.93	.96	9.0
ADFI, lb[d]	1.65	1.58	1.72	1.46	1.61	1.52	9.1
F/G[f]	1.72	1.58	1.72	1.60	1.73	1.59	3.5

[a]Five pens/treatment and four pigs/pen. Fermentation products were Fermacto® (FP) and Modified Fermacto (MFP).
[b]No treatment effect (P>.15).
[cdef]Meal vs pellet (P<.10, P<.05, P<.01, and P<.001, respectively).

Table 3. Effects of Fermentation Products on Nutrient Digestibility and Colony Forming Units (CFUs) of Fecal Microbes[a]

	1.15/.95% lysine control diet		1.05/.85% lysine + FP		1.05/.85% lysine + MFP		
Item	Meal	Pellet	Meal	Pellet	Meal	Pellet	CV
Apparent digestibility (d 14), %							
DM[f]	77.3	79.5	77.9	75.7	77.6	78.0	2.7
N[cef]	63.6	69.0	65.3	64.4	67.0	69.6	5.0
Fecal moisture (d 14), %[b]	78.2	79.1	77.3	79.7	76.3	78.5	5.8
CFUs of fecal microbes (d 14), $\log_{10}$							
Lactobacilli[b]	7.96	8.29	8.01	8.10	8.36	7.94	8.8
Streptococci[b]	4.25	4.16	3.38	3.76	3.86	2.94	32.1
Coliforms[b]	4.66	4.65	4.10	4.28	5.58	3.87	36.1
CFUs of fecal microbes (d 35), $\log_{10}$							
Lactobacilli[b]	7.94	6.89	6.07	7.32	6.74	7.15	21.1
Streptococci[df]	4.93	3.21	2.02	4.06	1.80	2.74	60.3
Coliforms[e]	5.99	5.90	5.59	4.93	6.66	6.25	19.0

[a]Fermentation products were Fermacto® (FP) and Modified Fermacto (MFP).
[b]No treatment effect (P>.13).
[c]Meal vs pellet (P<.10).
[d]Control vs fermentation products (P<.10).
[e]FP vs MFP (P<.05).
[f]Meal vs pellet × control vs fermentation products (P<.10).

EFFECT OF REPLACING MILK PROTEINS WITH WHEAT GLUTEN AND SOYBEAN PRODUCTS ON DIGESTIBILITY OF NUTRIENTS AND GROWTH PERFORMANCE IN NURSERY PIGS

B. T. Richert, J. D. Hancock, and J. L. Morrill

Summary

Two experiments were conducted to evaluate the nutritional value of processed wheat gluten for early-weaned pigs. The first experiment involved 72 weanling pigs with an avg age of 20 d and avg wt of 9.2 lb. Six diets were fed to the pigs in individual metabolism cages. Protein sources were casein, flash-dried wheat gluten, spray-dried wheat gluten, two solubilized wheat glutens, and soybean meal. Response criteria were N digestibility, biological value, and N retention. Casein had greater N digestibility, biological value, and N retention than the other protein sources. The wheat gluten products had greater N digestibility than soybean meal. Modification of the wheat gluten, to increase its solubility, resulted in marked decreases in biological value and N retention. Experiment 2 was a nursery growth assay. A total of 180 pigs were used, with an avg age of 25 d and avg wt of 12.3 lb. The five pelleted diets fed from d 0 to 14 were: 1) a high nutrient density diet (HNDD) with 20% dried whey and 20% dried skim milk (DSM); 2) HNDD with the DSM replaced by flash-dried wheat gluten and lactose; 3) HNDD with the DSM replaced by spray-dried wheat gluten and lactose; 4) HNDD with the DSM replaced by solubilized-modified wheat gluten and lactose; 5) HNDD with DSM replaced by soy protein isolate and lactose. All pigs were fed a common diet from wk 3 to 5 of the experiment. No differences in ADG or ADFI were noted for d 0 to 14. Feed to gain was best for pigs fed diets with spray-dried wheat gluten and worst for those fed diets with soy-isolate For d 0 to 35, pigs fed diets with flash-dried wheat gluten had lower ADG and ADFI than pigs fed diets with spray-dried and solubilized-modified wheat gluten. Furthermore, pigs fed spray-dried wheat gluten during Phase I had the greatest overall growth performance, with a 19% improvement in ADG compared to pigs fed DSM.

(Key Words: Starter, Dried Skim Milk, Wheat, Gluten, Process, Digestion, Performance.)

Introduction

The demand for milk products as human food can make their use in animal feeds impractical. Wheat gluten is commonly used in the bread making industry to improve low quality wheat flours, has 75% crude protein, and is priced much cheaper per unit of protein than dried skim milk. Four wheat gluten products, differing greatly in solubility and manufacturing process (i.e., flash-dried, spray-dried, solubilized, and solubilized plus further modifications) were evaluated as potential replacements for milk protein sources (especially dried skim milk) in diets for weanling pigs.

Procedures

In Experiment 1, 72 crossbred barrows were weaned at 20 d of age (avg wt of 9.2 lb) and started immediately on experimental diets. Pigs were individually housed in stainless steel metabolism cages to allow collection of feces and urine. The pigs were allowed to consume water ad libitum, and their daily feed allowance was calculated as .05 × body weight^{9}. Treatments were: 1) casein; 2) flash-dried wheat gluten[1]; 3) spray-dried wheat gluten[1]; 4) solubilized wheat gluten[1]; 5) solubilized and further modified wheat gluten[1]; and 6) soybean meal (Table 1).

The diets were fed for a 5-d adjustment period, followed by 4 d of total collection of feces and urine. The diets were fed four times per d at 6 h intervals. Room temperature was maintained at 82°F.

In Experiment 2, 180 crossbred pigs were weaned at 25 d of age (avg initial wt of 12.3 lb) and used in a 5-wk growth assay to determine the nutritional value of wheat gluten products and lactose as replacements for dried skim milk. Pigs were housed (three barrows and three gilts per pen) in 4 ft × 5 ft pens with woven wire flooring. Each pen had a self-feeder and nipple water to allow ad libitum intake.

The pigs were fed Phase 1 diets (Table 2) from weaning to d 14. Phase 1 treatments were pelleted and included: 1) a high nutrient density diet (HNDD) with 20% dried whey and 20% dried skim milk (DSM); 2) HNDD with the DSM replaced by flash-dried wheat gluten and lactose; 3) HNDD with the DSM replaced by spray-dried wheat gluten and lactose; 4) HNDD with the DSM replaced by solubilized-modified wheat gluten and lactose; 5) HNDD with DSM replaced by soy protein isolate and lactose. All Phase 1 diets contained .20% chromic oxide as an indigestible marker for determination of apparent digestibilities of DM and N. In phase 2 (d 14 to 35), all pigs were fed a common pelleted diet (corn-soybean meal- dried whey).

Pigs and feeders were weighed weekly to determine ADG, ADFI, and F/G. On d 14 of the experiment, fecal samples were collected from four pigs per pen. The fecal samples were dried and pooled within pen. The pooled samples were analyzed for DM, N, and Cr content to determine apparent digestibilities of DM and N.

[1]Wheat protein products were supplied by Midwest Grain Products, Inc., Atchison, KS.

Results and Discussion

In Experiment 1, diets with casein had greater N digestibility, biological value, and N retention than diets with the other protein sources (Table 3). The wheat glutens had N digestibilites that were slightly lower than casein but greater than soybean meal. The solubilized and solubilized-modified wheat gluten had lower biological value and N retention than the other wheat glutens.

In Experiment 2, no differences were noted in ADG, ADFI, or F/G for d 0 to 7, although pigs fed the HNDD diet with DSM had small numerical advantages in ADG and F/G compared to the other treatments (Table 4). For d 0 to 14, no differences were observed in ADG or ADFI, but pigs fed the wheat gluten products had better F/G than those fed the soy protein isolate. Pigs fed spray-dried wheat gluten had improved F/G compared to those fed solubilized-modified wheat gluten. The HNDD diet with DSM had greater apparent DM digestibility than the other diets.

Overall (d 0 to 35), pigs fed spray-dried wheat gluten and solubilized-modified wheat gluten had greater ADG and ADFI than pigs fed flash-dried wheat gluten. The spray-dried wheat gluten diet supported notably greater in ADG and ADFI when compared to all other diets.

In conclusion, wheat gluten products and lactose can effectively replace DSM in a Phase 1 diet. To d 14, relative feeding values (based on feed efficiency) of the diets with flash-dried, spray-dried, and solubilized-modified wheat gluten and soy protein isolate were 100, 109, 97 and 95%, respectively, compared to the HNDD diet with DSM. Furthermore, pigs fed spray-dried wheat gluten during Phase I had the greatest overall growth performance, with 19% greater ADG (.99 vs .83 lb/d) than pigs fed DSM during Phase I.

Table 1. Diet Composition (Experiment 1)

Ingredient, %	Casein-based control
Corn	32.76
Casein[a]	17.80
Corn starch	17.19
Lactose	20.00
Fish meal	5.00
Soy oil	3.00
Monocalcium phosphate	2.00
Limestone	.37
Amino acids	.33
Vit/Min/Antibiotic[b]	1.00
Salt	.30
Chromic oxide	.25
Total	100

[a]Flash-dried, spray-dried, solubilized, and solubilized-modified wheat gluten, soybean meal, monocalcium phosphate, limestone, and amino acids were substituted for casein and cornstarch to bring all diets to 22% CP, 1.54% lysine, .9% Ca, and .8% P.
[b]Antibiotic supplied per ton of diet: 100g chlortetracycline, 100g sulfathiazole, and 50g penicillin.

Table 2. Diet Composition (Experiment 2)

Ingredient, %	HNDD[a] d 0-14
Corn	33.51
SBM (48% CP)	20.20
Whey	20.00
DSM[a]	20.00
Soy oil	3.00
Monocalcium phosphate	1.20
Limestone	.34
Vit/Min/Antibiotic[c]	1.55
Chromic oxide	.20
Total	100

[a]Diets were fed from d 0 to 14. All pigs were fed a common corn-SBM-whey diet from d 14 to 35.
[b]Flash-dried, spray-dried, and solubilized-modified wheat gluten, soy isolate, lactose, monocalcium phosphate, limestone, lysine and .2% salt were substituted for the dried skim milk so that all diets had 22% CP, 1.4% lysine, .9% Ca, and .8% P.
[b]Antibiotic supplied per ton of diet: 200g furazolidone, 100g oxytetracycline, and 90g arsanilic acid.

Table 3. Nitrogen Digestibility and Utilization of Wheat Gluten Products (Experiment 1)[a]

Item	Casein	Flash-dried gluten	Spray-dried gluten	Solubilized gluten	Sol-mod gluten	Soybean meal	CV
N digestibility, %[b]	95.1	90.7	91.5	91.2	92.1	87.2	4.2
Biological value, %[c]	82.1	74.0	75.6	70.1	70.9	74.3	6.2
N retention, %[d]	78.3	68.2	68.3	63.4	65.8	65.5	8.3

[a]Twelve pigs/treatment for N digestibility and eight pigs/treatment for biological value and N retention.
[b]Casein vs others (P<.01); wheat glutens vs soybean meal (P<.01).
[c]Casein vs others (P<.01); solubilized and solubilized-modified vs flash- and spray-dried wheat glutens (P<.02).
[d]Casein vs others (P<.01).

Table 4. Effect of Wheat Gluten on Growth Performance and Nutrient Digestibility in Nursery Pigs (Experiment 2)[a]

Item	HNDD	Flash-dried wheat gluten	Spray-dried wheat gluten	Sol-mod wheat gluten	Soy isolate	CV
d 0 to 7						
ADG, lb[b]	.74	.69	.67	.71	.67	14.3
ADFI, lb[b]	.65	.61	.61	.65	.60	10.1
F/G[b]	.88	.90	.92	.92	.90	7.2
d 0 to 14						
ADG, lb[b]	.74	.70	.75	.71	.68	11.4
ADFI, lb[b]	.77	.74	.72	.77	.75	7.6
F/G[c]	1.05	1.05	.96	1.08	1.11	5.5
d 0 to 35						
ADG, lb[d]	.83	.85	.99	.89	.86	10.9
ADFI, lb[e]	1.27	1.26	1.49	1.37	1.32	10.3
F/G[b]	1.52	1.48	1.52	1.53	1.54	4.4
Apparent digestibility, %						
DM[f]	89.1	87.8	87.5	88.3	88.6	1.4
N[b]	85.9	86.4	86.3	85.7	86.5	2.1

[a]Six pigs/pen and six pens/treatment.
[b]No treatment effect (P>.10).
[c]Wheat glutens vs soy isolate (P<.01); spray-dried wheat gluten vs solubilized-modified wheat gluten (P<.01).
[d]Flash-dried wheat gluten vs spray-dried and solubilized-modified wheat gluten (P<.08).
[e]Flash-dried wheat gluten vs spray-dried and solubilized-modified wheat gluten (P<.02).

[f]HNDD with dried skim milk vs others (P<.07).

EFFECT OF FAT SOURCE AND LEVEL ON FINISHING PIG PERFORMANCE [1]

D. A. Nichols, J. L. Nelssen, J. D. Hancock, D. H. Kropf, and R. H. Hines

Summary

Two hundred and forty finishing pigs were utilized to evaluate the effect of fat source and level on growing pig performance and carcass characteristics. Pigs were fed a milo-soybean meal diet balanced on a constant energy:lysine and energy:protein ratio. Dietary treatments were: 1) control; 2,3,4) 2.5, 5.0, or 7.5% added soybean oil; 5 and 6) 5.0 or 7.5% added tallow. In comparing pigs fed soybean oil to tallow, there were no significant effects on feed intake, average daily gain, or feed to gain ratio. Soybean oil additions compared to tallow resulted in carcasses with significantly more average backfat as well as 10th rib fat depth. In addition, carcass firmness was significantly reduced as level of soybean oil addition was increased compared with tallow addition.

(Key Words: G-F, Performance, Fat, Source, Carcass.)

Introduction

Fat is an excellent feed source for finishing pigs. It is an energy dense, highly palatable, feed ingredient and can increase daily gain and improve feed efficiency. In addition, it can reduce dustiness and equipment wear. Recently, interest in fat additions has been renewed. The purpose of this study was to examine the effect of fat source on performance and carcass traits of finishing swine.

Procedures

Two hundred forty pigs were assigned to one of the following dietary treatments:

1. Control: corn/soybean meal diet
2. Control plus 2.5% soybean oil
3. Control plus 5.0% soybean oil
4. Control plus 7.5% soybean oil
5. Control plus 5.0% tallow
6. Control plus 7.5% tallow

Pigs were housed in a modified open front building with 8 pigs/pen and 5 pens/treatment. Diets were balanced on a constant energy: lysine and energy:protein ratio. Pigs were started on experiment at an initial weight of 120 lb and were terminated when the weight of pigs in a pen averaged 230 lb. Pigs were weighed bi-weekly, and average daily feed intake, average daily gain, and pen feed efficiency were determined.

Upon completion of the feeding portion of the experiment, two pigs per pen were randomly selected to evaluate treatment effects on carcass characteristics. Response criteria measured included dressing percentage, average backfat thickness, 10th rib fat depth, loin-eye area, carcass grade, and percentage muscle. In addition, a series of fat biopsies were taken from each carcass to determine fatty acid profiles.

These data were used to determine if feeding high levels of soybean oil adversely affects carcass quality and fat composition.

[1]Special appreciation to the American Soybean Association for partial funding of this project.

Results and Discussion

As most previous studies have established, increasing energy level of the diet reduced feed intake (Table 1). With added fat, the average daily feed intake for pigs in this study was reduced 12% (P<.002). Source of fat did not significantly change feed intake. When soybean oil addition was increased from 2.5% to 5.0% and 7.5%, we observed a numerical reduction in feed intake. On the other hand, increasing tallow from 5.0% to 7.5% had little or no effect on feed intake. During the feeding period, Manhattan experienced severe cold weather, which may have increased variability of feed consumption.

Feed to gain ratio was improved (P<.001) with addition of fat, regardless of source. Higher levels of fat (5.0 and 7.5%) resulted in lower feed to gain ratio than the 2.5% soybean oil addition (P<.02). No differences were observed between fat sources for feed to gain ratio.

Treatment effects on carcass traits are presented in Table 2. Fat source or level had no effect on dressing percent (P>.17), loin eye area (P>.17), carcass length (P>.18), or percentage lean (P>.13). Fat source did affect average and 10th rib backfat thickness. Pigs fed soybean oil had higher average backfat thickness (P<.01) than those fed tallow. In addition, soybean oil addition tended to increase 10th rib fat depth compared to tallow addition.

When tissue samples were taken for laboratory analysis, carcasses were scored for firmness. Hams and loins were scored for marbling, color and firmness. Results are presented in Table 3. No treatment effects were observed for ham marbling, loin color, or loin firmness.

A fat source by fat level interaction was observed when we evaluated ham color. Increasing levels of soybean oil tended to reduce ham color scores, whereas increasing tallow levels tended to increase ham score. Hams from soybean oil-fed pigs had lower firmness scores (P<.01) than hams from tallow-fed pigs.

When loins were evaluated we observed a (P<.05) linear effect of fat level on marbling. As fat level increased, marbling score increased, regardless of fat source. No differences were observed in loin color or firmness (P>.10).

Prior to tissue collection, we subjectively evaluated carcasses for firmness by handling the belly wall as well as applying pressure to the outside of the subcutaneous fat layers. Upon analysis, a fat level as well as fat source effect was observed. Carcasses from pigs fed soybean oil were softer (P<.01) than those from pigs fed tallow. Increasing level of soy oil resulted in a significant reduction in firmness score, both at the 5% and 7.5% dietary level.

In comparing soybean oil to tallow, we can make the following conclusions:

1. Fat source had no significant effects on feed intake, average daily gain, or feed to gain ratio.
2. Soybean oil addition compared to tallow addition resulted in carcasses with significantly more average backfat, as well as 10th rib fat depth.
3. Hams from soybean oil-fed pigs were significantly softer than those from tallow-fed pigs.
4. Carcass firmness was significantly reduced as level of soy oil addition was increased, compared with tallow addition.
5. Sensory panel analysis showed that all dietary treatments resulted in acceptable pork quality.
6. Differences in fatty acid profiles between soybean oil- and tallow-fed pigs can be explained based on composition of the fat sources.
7. Feed efficiency continued to improve linearly with increasing soybean oil addition to finishing swine diets.

Table 1. Least Square Means for Performance Traits

		Soybean oil, %			Tallow, %		
Item	Control	2.5	5.0	7.5	5.0	7.5	CV
Average daily gain, lb[a]	1.94	1.87	1.98	1.97	1.90	1.97	6.4
Average daily feed, lb[b]	7.14	6.56	6.48	6.11	6.05	6.16	7.7
Feed to gain ratio[c]	3.70	3.50	3.27	3.10	3.17	3.13	5.3

[a]No treatment effect (P>.19).
[b]Control vs added fat (P<.002).
[c]Control vs added fat (P<.001); 2.5% soy vs 5.0% and 7.5% soy and tallow (P<.002).

Table 2. Least Square Means for Carcass Traits

		Soybean oil, %			Tallow, %		
Item	Control	2.5	5.0	7.5	5.0	7.5	CV
Dressing percent	74.49	74.92	74.60	75.10	74.91	74.90	1.9
Loin eye area, in^2	4.9	5.53	5.19	5.61	5.01	5.40	13.3
Length, in	31.1	30.7	30.7	30.6	31.2	30.9	2.3
Average backfat, in[a]	1.37	1.37	1.40	1.41	1.24	1.28	10.7
10th rib backfat, in[b]	1.30	1.21	1.29	1.25	1.26	1.17	17.9
Percent lean	50.50	51.98	50.93	51.66	52.08	52.14	4.6

[a]Soy oil vs tallow (P<.05).
[b]Soy oil vs tallow (P<.10).

Table 3. Least Square Means for Carcass Marbling, Color and Firmness

		Soybean oil, %			Tallow, %		
Item	Control	2.5	5.0	7.5	5.0	7.5	CV
Ham							
Marbling	2.34	2.16	2.04	1.77	2.10	2.07	12.9
Color	2.89	3.13	2.89	2.76	2.72	2.96	5.9
Firmness[a]	2.79	2.56	2.46	1.99	2.86	2.79	8.6
Loin							
Marbling	2.86	3.13	2.31	2.86	2.37	2.79	10.9
Color	2.69	2.99	2.72	2.76	2.60	2.99	8.8
Firmness	2.69	3.03	2.62	2.56	2.60	2.89	8.3
Total carcass firmness[b,c,d]	7.08	5.11	4.24	2.66	6.76	6.20	18.9

[a]Soy oil vs tallow (P<.05).
[b]Soy oil vs tallow (P<.10).
[c]Control vs added fat (P<.05).
[d]1=very soft, 10=very firm.

SELECTION FOR INCREASED IN VITRO DIGESTIBILITY IMPROVES FEEDING VALUE OF SORGHUM GRAIN

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Summary

Six cannulated barrows and two hundred eighty-eight chicks were used in an experiment to determine the value of an in vitro protein digestibility assay (pepsin digest) for identification of sorghum parent lines with improved nutritional value. The barrows were used to determine digestibility of the experimental sorghums at the terminal ileum and for the total digestive tract. Due to a limited supply of the sorghums, broiler chicks were used as a model to predict the value of the experimental sorghums for growth performance. Four sorghum parent lines were selected from 100 S_1 families grown at several locations in Kansas. Two of the sorghums were consistently low and two were consistently high for in vitro digestibility. Treatments were: 1) corn-soybean meal control; 2) and 3) low digestibility sorghums (LD1 and LD2); 4) and 5) high digestibility sorghums (HD1 and HD2); and 6) pearl millet (PM). The sorghums that had consistently high in vitro digestibility were of greater nutritional value to pigs and growing chicks than sorghums with low in vitro digestibility. In the pig experiment, digestibility of N at the terminal ileum ranged from 69.6% for LD1 to 79.0% for HD1, compared to 81.6% for the corn-based control. Similar responses were noted for digestibility of gross energy, with values of 71.8% and 77.0% for LD1 and HD1, compared to 80.2% for the corn-based control. The HD lines were equal or nearly equal to corn in the chick growth assay, with efficiencies of gain that were 98 and 100% that of corn for HD1 and HD2, respectively. Pearl millet was of greater feeding value than sorghums for chicks but less digestible than sorghums in pigs. These data suggest that in vitro pepsin digestibility can be a valuable tool for sorghum breeders to select parent lines with improved feeding value.

(Key words: Performance, GF, Ileal, Digestibility, Sorghum, Millet, Corn.)

Introduction

Sorghum grain is often viewed as a substitute for corn, with somewhat lower feeding value. That image is due largely to variation in nutrient content and quality. An ongoing research project, by plant breeders in the KSU Department of Agronomy, has identified parent lines of sorghum with high in vitro digestibility. However, the true merit of these sorghums, selected by using the in vitro assay, must be determined in animal feeding experiments. Two experiments were conducted to determine the nutritional value of sorghums that were selected for high digestibility by using an in vitro pepsin digestibility procedure.

Procedures

Four sorghums that had different in vitro protein digestibilities were selected from 100 S_1 families grown for 2 yr at several locations in Kansas. Two of the sorghums consistently had low in vitro digestibility and two consistently had high in vitro digestibility. Treatments were: 1) corn-soybean meal control; 2) and 3) low digestibility sorghums (LD1 and LD2); 4) and 5)

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high digestibility sorghums (HD1 and HD2); and 6) pearl millet (PM). LD1 had high tannin and LD2 had corneous (hard) endosperm. The grains were grown during 1988 and 1989, and fed during 1989 and 1990, respectively. Grain produced in both years was used in the chick growth assay, but quantities of the grains were sufficient only from the 1989 crop to allow the pig feeding experiment in 1990.

For the digestibility experiment, six barrows (avg initial wt of 87.8 lb) were surgically fitted with T-cannulas at the terminal ileum. These cannulated pigs were used in an experiment to determine apparent digestibilities of DM, N, and GE. A diet was formulated to contain 15% crude protein, .65% Ca, and .55% P with the corn treatment (Table 1). The other grain sources replaced corn on a lb for lb basis. Feed allotments were determined as $.05 \times BW^{.9}$, with BW in kg. Feed was offered at 7 a.m. and 7 p.m. as a wet mash. Water was consumed ad libitum. The experimental design was a six by six Latin square, where each grain source was fed to each pig in one of the six feeding periods. The feeding periods lasted 7 d, with a 4-d adaptation period, 36-h of fecal collection, and 11-h collections of ileal digesta on d 6 and 7. Digesta was collected into containers immersed in an ice-water bath. Digesta and fecal samples were homogenized, subsampled, frozen, and subsequently freeze-dried and analyzed for DM, N, and GE.

For the growth assay, 288 chicks (7 d of age) were used in a 14-d experiment. The chicks were housed with four birds/cage and 12 cages/treatment. The diets were formulated to contain 24% CP, 1.1% Ca and .9% P. Feed and water were consumed ad libitum. Chicks were weighed at the end of the experiment and feed consumption was recorded. Response criteria were gain, feed intake and F/G.

Results and Discussion

Results from the experiment with pigs (Table 2) indicated that ileal and total tract digestibilities of DM, N, and GE were greater for corn than the other grains. Ileal and total tract digestibilities of DM, N, and GE were greater for the HD sorghums than LD sorghums. Digestibilities of DM, N, and GE were greater for LD2 than LD1, suggesting that the tannin content of LD1 had a greater negative effect than the hard endosperm of LD2. Ileal N digestibilities for LD1, LD2, HD1, HD2, and PM were 85, 94, 97, 96, and 95% that of corn, respectively. Ileal GE digestibilities for LD1, LD2, HD1, HD2, and PM were 90, 94, 96, 95, and 91% that of corn, respectively.

From the growth assay, chicks fed the HD sorghums gained more weight than chicks fed LD sorghums (Table 2). Weight gains for chicks fed LD1, LD2, HD1, HD2 and PM were 95, 96, 98, 100, and 99% of weight gains for chicks fed the corn-based diet. Feed intake was not affected by treatment. Efficiency of gain was greater for chicks fed HD sorghums than chicks fed LD sorghums. Feeding values (i.e., efficiencies of gain) for LD1, LD2, HD1, HD2 and PM were 95, 97, 98, 100 and 100% of the corn-based control diet.

In conclusion, these data suggest that an in vitro pepsin assay was effective as a predictor of feeding value for sorghum grain. In pigs, ileal and total tract digestibilities of the HD sorghums were improved compared to LD sorghums, but were still of lower digestibility than corn. Broiler chicks were able to utilize nutrients from the HD sorghums and millet essentially as well as nutrients from corn.

Table 1. Composition of Experimental Diets, %[a]

Ingredient	Pig digestibility	Chick growth
Grain source	77.58	51.14
Soybean meal (48% CP)	19.46	40.42
Soybean oil	—	3.50
DL-methionine	—	.23
Vit/Min/Antibiotic mix[b]	2.96	4.71

[a]Pig diets were formulated to have 15% CP, .65% Ca, and .55% P. Chick diets were formulated to have 24% CP, 1.1% Ca, and .9% P.
[b]Antibiotic was amprolium (.05%) and chlortetracycline (100 g/ton) for chick diets.

Table 2. Apparent Digestibilities in Growing Pigs and Chick Growth Performance

Item	Corn	LD1	LD2	HD1	HD2	Millet	CV
Ileal digestibility in pigs, %[a]							
DM[cfh]	79.3	71.6	74.8	76.4	75.9	73.1	4.3
N[cgj]	81.6	69.6	77.1	79.0	78.6	77.7	4.1
GE[cfi]	80.2	71.8	75.4	77.0	76.5	73.3	4.2
Total tract digestibility in pigs, %[a]							
DM[dgjl]	90.2	85.0	88.9	88.6	89.1	86.0	1.0
N[dgjk]	87.3	71.7	82.1	83.0	82.6	84.1	3.5
GE[dgjl]	89.5	83.3	87.7	87.5	87.9	84.4	1.1
Chick performance[b]							
Gain, lb[e]	1.06	1.00	1.02	1.04	1.06	1.05	7.8
F/G[e]	1.53	1.61	1.57	1.56	1.53	1.52	5.5

[a]Six cannulated barrows in a six by six Latin square (six observations per treatment).
[b]288 chicks, 5 chicks/cage, 12 cages/treatment.
[cd]Corn vs others (P<.01, P<.001, respectively).
[efg]LD1 and LD2 vs HD1 and HD2 (P<.11, P<.05, P<.001, respectively).
[hij]LD1 vs LD2 (P<.11, P<.07, P<.001, respectively).
[kl]Sorghums vs millet (P<.01, P<.001, respectively).

THE EFFECT OF SUPPLEMENTAL FAT AND LYSINE ON FINISHING PIG PERFORMANCE AND CARCASS CHARACTERISTICS

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Summary

One hundred and sixty pigs averaging 127.4 lb were used to determine the benefit of 5% supplemental fat and (or) .20% lysine on growth performance and carcass characteristics. The trial consisted of four treatments: 1) a .61%, lysine milo-soybean meal control diet; 2) control + 5% fat; 3) control + .20% lysine; 4) control + 5% fat and .20% lysine. Lysine:metabolizable energy ratios were held constant at 1.91:1 for treatments 1 and 2 and at 2.52:1 for treatments 3 and 4. Pig weights and feed consumption were recorded every third wk to calculate average daily gain (ADG), average daily feed intake (ADFI), and feed/gain (F/G). At the termination of the experiment, pigs were scanned via ultrasound for 10th rib backfat thickness (BF) and loineye area (LEA). High and low ambient temperatures were monitored to evaluate growth performance relative to temperature. Improvements in feed efficiency were detected when supplemental fat was added to the diet from d 0 to 21. During this period, the average temperature fluctuated from a low of 67.4
93.4 the hottest of the experiment, with a mean temperature of 80.4
d. Average daily gain increased 5 to 8% with supplements of fat or the combination of both fat and lysine to the diet. From d 21 to 42, no differences in performance were detected for diets supplemented with fat and(or) lysine. Overall, supplemental fat tended to improve feed efficiency by 8 to 14% in control and lysine-supplemented diets, respectively. Differences in ADG and ADFI were not detected over the entire trial. Supplemental fat increased BF and tended to reduce LEA. Supplemental lysine increased LEA with no effect on BF. These data suggest that supplemental fat and (or) lysine can be beneficial during periods of temperature above 90
benefit to supplementing lysine in combination with fat was not detected.

(Key Words: Performance, Fat, Lysine, G-F.)

Introduction

Pigs in the growing-finishing stage obtain maximum performance at their thermal neutral zone of 55-85 erature range, body maintenance requirements are at their lowest levels. At temperatures below this zone, the pig requires increased energy intake for body maintenance. Thus, increased feed intakes are detected in conjunction with poorer feed efficiency as a result of the body's need to maintain heat production. Conversely, temperatures above the thermal neutral zone depress feed intake. The pig consumes less feed during periods of high temperatures, which decreases the heat dissipated throughout the body from nutrient metabolism; however, the pig retains a high maintenance requirement through increased efforts to dissipate heat. Decreased growth rates are typical during periods of high temperatures because of the decrease in feed intake. A solution to this decreased performance is to supplement diets with fat and (or) lysine during the summer months. Adding fat and(or) lysine to the diet does not increase intakes but increases nutrient density of the diet. The pig does not consume more feed, but the feed that is consumed contains higher energy and amino acid concentrations for growth. Thus, the objective of this study was to evaluate the effect of supplemen-

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tal fat and(or) lysine to finishing diets. Subsequential carcass characteristics were also obtained to determine treatment effects upon carcass merit.

Procedures

A total of 160 crossbred pigs averaging 127.4 lb were utilized to determine the effects of supplemental fat and lysine to finishing diets. The trial consisted of four dietary treatments: 1) a .61% lysine, milo-soybean meal control; 2) control + 5% fat; 3) control + .20% lysine; and 4) control + 5% fat and .20% lysine. Experimental diets were formulated to contain .66% calcium and .55% phosphorus (Table 1). A constant lysine: calorie ratio (grams lysine per Mcal energy) was maintained between treatments 1 and 2 (1.91:1) and between treatments 3 and 4 (2.52:1). By maintaining equal lysine:energy ratios, the response to added fat could be determined without lysine limiting performance. Pigs were blocked by weight and by sex into four blocks of four replicate pens. Each pen contained 10 pigs. Pigs were housed in a modified open-front building. Pens had 50% slatted floor and 50% solid floor. Each pen contained a self-feeder and a nipple waterer, providing feed and water ad libitum. Drip coolers were utilized during the experiment and cycled on for a period of 3 min out of 15 min when temperatures exceeded 85

Pig weights and feed consumption were collected every third wk of the trial. Pigs were removed from the trial when the average weight of all pigs in a pen was 230 lb. Average daily gain (ADG), ADFI, and F/G were calculated at each weigh period. High and low temperature readings were taken each day to assess thermal environment effects on growth performance. At the termination of the trial, BF and LEA were measured ultrasonically (Technicare 210DX, Johnson and Johnson Co.).

Results and Discussion

Average daily gain and ADFI were not affected by supplemental fat and(or) lysine during the first 21 d of the trial. However, an improvement in F/G ($P<.05$) was detected for pigs fed the diets containing 5% supplemental fat (Table 2). Numerical improvements of 5 to 8% were detected in ADG with additions of fat to either the control diet or the diet + .20% lysine. Pigs fed diets containing .20% added lysine tended to have a 7 and 8% improvement in ADG. The average high temperature during this period was 94

1). The high temperatures resulted in decreased feed intake during the first 21 d of the trial compared to the second 21 d period. Decreased intakes during d 0 to 21 would correlate to temperatures above the maximum temperature of the thermal neutral zone. After d 21, average high temperatures were 80-85 (Figure 1), at which the pig is within the thermal neutral zone. Growth performance was not altered by supplementing fat and lysine to the diets from d 21 to 42, though tendencies for increases up to 12% in ADG were detected for pigs fed the combination of supplemental fat and lysine. Feed efficiency tended to be improved by supplements of either fat or lysine during this period. In the overall trial, F/G tended to improve with 5% supplemental fat ($P<.10$) to either the control diet or the control + .20% lysine diet. Average daily gain was similar across treatments, with a slight numerical increase when the diet was supplemented with both fat and lysine.

These data show that the thermal environment plays a role in finishing pig performance. Though significant differences were not detected in ADG with supplemental fat and lysine, improvements in F/G were detected ($P<.05$). As average temperatures decreased after d 21 of the trial, treatment differences were less evident. This suggests that pigs do not require addition energy and lysine during periods of ambient temperature within the thermal neutral zone.

Carcass quality was altered by supplements of fat and lysine to the control diet (Table 2). Backfat thickness was improved ($P<.10$) when fat was supplemented to the diets. Lysine supplementation did not have an effect upon BF thickness. Loineye area was increased (P<.05) by diets supplemented with lysine; however, decreases in LEA (P<.10) were detected with supplemental fat. These data indicated that though supplemental fat improves F/G, increases in BF and decreases in LEA result as a consequence. Additional lysine increases LEA by providing more amino acid available for lean growth.

Table 1. Composition of Diets

Ingredient, %	Control	Control + 5% Fat	Control + .2% Lysine	Control + 5% Fat + .2% Lysine
Sorghum	88.73	76.96	77.00	69.90
Soybean meal, 48%	13.33	15.09	20.20	22.31
Soybean oil		5.00		5.00
Monocalcium phosphate	1.09	1.13	0.97	1.00
Limestone	0.95	0.92	0.93	0.89
Salt	0.25	0.25	0.25	0.25
Vitamin premix	0.25	0.25	0.25	0.25
Trace mineral premix	0.10	0.10	0.10	0.10
Selenium premix	0.05	0.05	0.05	0.05
Antibiotic[a]	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00
Calculated Analysis				
Lysine, %	0.61	0.65	0.81	0.86
Metabolizable energy, Kcal/lb	1,451	1,541	1,456	1,548
Lysine:Energy, g/Mcal	1.91	1.91	2.52	2.52
Ca, %	.66	.66	.66	.66
P, %	.55	.55	.55	.55

[a]Chlortetracycline.

Table 2. Growth Performance and Carcass Traits for Pigs Fed Diets Containing Supplemental Fat and(or) Lysine

Item	Control	Control + 5% Fat	Control + .2% Lysine	Control + 5% Fat + .2% Lysine	CV
d 0 to 21					
ADG, lb	1.50	1.57	1.61	1.74	11.9
ADFI, lb	6.29	5.42	6.16	6.28	10.4
F/G[a]	4.25	3.46	3.84	3.63	11.5
d 21 to 42					
ADG, lb	1.77	1.65	1.70	1.87	11.6
ADFI, lb	6.57	5.97	6.50	6.41	8.8
F/G	3.74	3.63	3.86	3.46	11.6
d 0 to 63					
ADG, lb	1.78	1.75	1.71	1.88	9.0
ADFI, lb	6.43	5.87	6.49	6.32	7.3
F/G[c]	3.63	3.37	3.84	3.36	11.7
10th rib BF, in[cd]	0.79	0.89	0.80	0.89	22.2
LEA, in[bcd]	4.73	4.56	4.90	4.78	10.2

[a]Fat effect (P<.05).
[b]Lysine effect (P<.05).
[c]Fat effect (P<.10).
[d]NPPC equations utilized to adjust measurements based upon 230 lb live weight.

Figure 1. High, Low, and Average Temperatures for the Trial.

COMPARISON OF CONVENTIONAL AND LOW-INHIBITOR SOYBEANS WITH DIFFERENT HEAT TREATMENTS AND LYSINE CONCENTRATIONS IN DIETS FOR FINISHING PIGS

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Summary

Two experiments were conducted to determine the effects of gene expression for the Kunitz trypsin inhibitor, heat treatment, and concentration of lysine in the diet on nutritional value of soybeans for finishing pigs. In Experiment 1, 108 pigs (113 lb avg initial wt) were fed diets with two soybean cultivars (Williams 82 and Amsoy 71), with (+K) and without (-K) gene expression for the Kunitz trypsin inhibitor, subjected to three heat treatments (1/2-, 3/4-, and full-roasting). Nutritional value of the Williams 82 and Amsoy 71 cultivars was not different, but -K soybeans were superior to +K soybeans at all levels of heat treatment. Results indicated that full-roasted -K soybeans were of the greatest nutritional value, and 3/4-roasted -K soybeans were of equal nutritional value to full-roasted +K soybeans. In Experiment 2, Amsoy 71 soybeans (+K and -K) were fed raw and extruded, at 80 and 110% of the lysine concentration recommended by the NRC. Growth performance was improved by feeding the -K vs +K, extruded vs raw, and 110 vs 80% treatments. Additionally, the -K soybeans supported greater performance than +K soybeans, even when both were fully processed and fed in diets above the lysine requirement for finishing pigs.

(Key Words: GF, Process, Soybeans, Trypsin Inhibitors, Lysine.)

Introduction

In the 1989 KSU Swine Day Report (page 65), we reported that heat treatment of Williams 82 soybeans with (+K) and without (-K) the Kunitz trypsin inhibitor gave improvements in growth performance of finishing pigs. These improvements in growth performance seemed to plateau between 1/2- and full-roasting time, but with treatments of none, 1/2-, and full-roasting, it was not possible to determine if less than full-roasting (e.g., 3/4-roasting) might be sufficient to optimize nutritional value of the +K and(or) -K soybeans. A second observation was that -K soybeans were of greater nutritional value than +K soybeans at all levels of heat treatment, even with full-roasting. Those differences were observed in diets that were formulated to be deficient in lysine (i.e., 80% of NRC) to accentuate differences in protein quality.

With those observations in mind, two experiments were conducted to determine if reduced roasting time of -K soybeans would yield a soybean product of equal or greater nutritional value than fully processed, conventional soybeans and to determine if -K soybeans were of greater nutritional value than +K soybean in diets that were adequate as well as deficient in lysine concentration.

Procedures

Experiment 1 was conducted at the University of Nebraska to determine the effects of roasting +K and -K soybeans on growth performance of finishing pigs. Two soybean

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cultivars (Williams 82 and Amsoy 71), each with +K and -K isolines, were heat processed for 1/2-, 3/4- and full-roasting times in a Roast-A-Tron® roaster (i.e., a 2×2×3 factorial arrangement of treatments). Full roasting was a throughput of approximately 1000 lb/h and an exit temperature of 245°F. Three-fourths- and 1/2-roasting treatments were accomplished by increasing throughput to 1,500 lb/h and 2,000 lb/h, respectively. The soybeans were ground through a hammermill, and added to 12 corn-soybean-based diets (Table 1). The diets were formulated to supply .48% lysine (i.e., 80% of the NRC requirement) to ensure that differences in protein quality would be detected. One hundred eight finishing pigs (nine pigs/treatment) were individually penned and fed from 113 to 219 lb. Response criteria included ADG, ADFI, F/G, and last rib fat depth.

Experiment 2 was conducted at Kansas State University, to determine the effects on finishing pigs of feeding raw and heat processed +K and -K soybeans at 80 and 110% of the NRC requirement for lysine, with a 2×2×2 factorial arrangement of treatments. The +K and -K soybeans were the Amsoy 71 cultivar, and heat processing was extrusion in a Wenger extruder with a barrel temperature of 300°F. The raw soybeans were ground through a hammermill before being added to the experimental diets, but the extruded soybeans required no further processing before use. The treatments were fed to 80 finishing pigs (two pigs/pen and five pens/treatment), with an avg initial wt of 124 lb and an avg final wt of 219 lb. Response criteria were ADG, ADFI, F/G, last rib fat depth, and digestibilities of DM and N.

Results and Discussion

No differences were observed for pigs fed the two soybean cultivars in Experiment 1 (Table 2). Furthermore, there were no interactions between soybean cultivar and gene expression for the Kunitz trypsin inhibitor (+K and -K) or duration of heat treatment (1/2-, 3/4-, and full-roast). Thus, differences between +K and -K isolines and 1/2-, 3/4-, and full-roasting treatments were consistent for both soybean cultivars.

Pigs fed -K soybeans had 5% greater ADG (1.93 vs 1.84 lb) and a 3% improvement in F/G (3.38 vs 3.49) compared to pigs fed the +K soybeans. Increasing time of heating from 1/2- to full-roasting improved ADG by 8%, F/G by 7%, and last rib fat depth by 8%. Of particular interest was that -K soybeans were of greater nutritional value than +K soybeans at all heat treatments. This was a surprise, because with full-roasting, trypsin inhibitor activities for +K and -K soybeans would be sufficiently low to give similar growth performance. However, these results are in agreement with the data we reported in the KSU 1989 Swine Report (page 65). Thus, less processing time (i.e., 3/4-roasting) can be used with -K soybeans to give performance equal to that obtained with fully processed +K soybeans, or full-processing of -K soybeans can be used to yield a soybean product of greater nutritional value than fully processed +K soybeans.

For Experiment 2, pigs fed -K soybeans had improved ADG and F/G and greater digestibilities of DM and N than pigs fed +K soybeans (Table 3). One objective of this experiment was to determine if improved nutritional value of -K soybeans would be observed with a different form of heat processing, i.e., extrusion rather than roasting. Extrusion processing improved the nutritional value of both soybean isolines, but -K soybeans were still of greater nutritional value than +K soybeans even with adequate heat treatment.

Increasing lysine concentration of the diets from 80 to 110% of NRC improved growth performance of pigs fed +K or -K soybeans, raw or extruded. With digestibility of raw -K soybeans being only slightly lower than that of fully roasted +K soybeans in previous experiments, it seemed possible that feeding an excess of lysine in diets with raw -K soybeans might meet the pig's needs for amino acids, even with slightly reduced nutrient digestibilities. This was not the case in the current experiment, with growth performance of pigs fed extruded +K soybeans being greater than that of pigs fed raw -K soybeans. Factor(s) other than decreased nutrient digestibility must have limited growth of pigs fed the raw soybeans. Alternatively, extruded -K soybeans were of greater nutritional value than extruded +K soybeans at 80 and 110% of NRC for lysine. This response was particularly surprising, because differences in protein sources are typically not observed when diets are formulated such that amino acids are in excess of their requirements. A similar response in nursery pigs fed extruded -K soybeans in protein-adequate diets is reported elsewhere in this publication (Hancock et al.).

In conclusion, -K soybeans required 25% less heat treatment to support growth performance equal to fully processed +K soybeans. Full-processing (roasting or extruding) of -K soybeans resulted in greater growth performance than full-processing of +K soybeans. This response was observed not only in the protein-deficient diet formulations (Experiment 1) used to measure quality of these protein sources, but also in diets above the current NRC recommendation for lysine (Experiment 2).

Table 1. Composition of Diets, %

	Experiment 1				Experiment 2			
	Williams 82		Amsoy 71		+K		-K	
Ingredient	+K	-K	+K	-K	80%	110%	80%	110%
Corn	84.65	84.65	84.65	84.65	84.72	74.62	84.72	74.62
Soybeans[a]	10.95	11.55	11.65	11.00	11.44	20.56	10.47	19.26
Cornstarch	1.15	.55	.45	1.10	.84	1.82	1.81	3.12
Vitamins and minerals	3.25	3.25	3.25	3.25	3.00	3.00	3.00	3.00

[a]The raw soybeans were analyzed for lysine concentration, and diets were formulated to .48% lysine in Experiment 1 and .48% (80% of NRC) and .66% (110% of NRC) lysine in Experiment 2. One-half, 3/4-, and full-roasted soybeans were substituted (protein basis) for the raw soybeans in Experiment 1. Extruded soybeans were substituted (protein basis) for the raw soybeans in Experiment 2.

Table 2. Effect of Cultivar, Roasting Time, and Gene Expression for the Kunitz Trypsin Inhibitor on Nutritional Value of Soybeans for Finishing Pigs[a]

	Williams 82						Amsoy 71						
	+K			-K			+K			-K			
Item	1/2	3/4	Full	1/2	3/4	Full	1/2	3/4	Full	1/2	3/4	Full	CV
Growth performance													
ADG, lb[be]	1.79	1.87	1.92	1.92	1.92	1.98	1.74	1.76	1.98	1.83	1.98	1.96	11.1
ADFI, lb[h]	6.44	6.61	6.46	6.86	6.53	6.50	6.19	6.22	6.68	6.44	6.53	6.26	9.4
F/G[cf]	3.60	3.53	3.36	3.57	3.40	3.28	3.56	3.53	3.37	3.52	3.30	3.19	6.7
Last rib fat													
depth, in[dg]	1.18	1.14	.98	1.18	1.02	1.06	1.10	1.10	1.14	1.14	1.10	1.06	14.9

[a]Values are means for five barrows and four gilts, fed individually, from 113 to 219 lb.
[bc]+K vs -K (P<.05, P<.01, respectively).
[def]Roasting time linear (P<.05, P<.01, P<.001, respectively).
[g]+K vs -K × roasting time linear (P<.10).
[h]No treatment effect (P>.10).

Table 3. Growth Performance and Nutrient Digestibility in Finishing Pigs Fed Soybeans with (+K) and Without (-K) the Kunitz Trypsin Inhibitor, Raw and Extruded in Diets Formulated to Provide 80 and 110% of the Lysine Requirement[a]

	+K				-K				
	Raw		Extruded		Raw		Extruded		
Item	80%	110%	80%	110%	80%	110%	80%	110%	CV
Growth performance									
ADG, lb[bhi]	1.44	1.57	1.62	1.77	1.48	1.64	1.83	1.95	10.4
ADFI, lb[l]	6.21	6.13	6.14	6.11	6.17	6.14	6.58	6.57	8.7
F/G[chj]	4.31	3.90	3.79	3.45	4.17	3.74	3.60	3.37	4.1
Last rib fat									
depth, in[g]	.74	.72	.63	.61	.75	.63	.63	.64	18.5
Apparent digestibility, %									
DM[be]	80.7	81.0	81.5	83.5	84.4	82.1	85.7	85.6	4.0
N[dfk]	64.3	66.5	63.0	74.8	72.7	72.0	78.2	77.2	8.5

[a]Values are means for five pens/treatment and two pigs/pen, fed from 124 to 219 lb.
[bcd]+K vs -K (P<.05, P<.01, P<.001, respectively).
[efgh]Raw vs extruded (P<.10, P<.05, P<.01, P<.001, respectively).
[ij]Lysine concentration (P<.05, P<.001, respectively).
[k]+K vs -K × lysine concentration (P<.05).
[l]No treatment effect (P>.18).

EXTRUSION OF SORGHUM, SOYBEAN MEAL, AND WHOLE SOYBEANS IMPROVES GROWTH PERFORMANCE AND NUTRIENT DIGESTIBILITY IN FINISHING PIGS

J. D. Hancock, R. H. Hines, and T. L. Gugle

Summary

One hundred forty-four finishing pigs (124 lb avg initial wt) were used to determine the effects of extruding sorghum, soybean meal (SBM), and whole soybeans on growth performance and nutrient digestibility. Treatments were: 1) control diet with ground sorghum, SBM, and soybean oil; 2) diet 1 with the ground sorghum, SBM, and soybean oil blended and extruded; 3) sorghum and whole soybeans extruded separately and blended; and 4) sorghum and extruded soybeans blended and extruded together. Extrusion was in an Insta-Pro® extruder. All diets were formulated to be equal in concentrations of metabolizable energy (ME) and lysine. Pigs fed diets with extruded ingredients had improved F/G. Extrusion of sorghum and extruded soybeans together was of greater benefit than extruding those ingredients separately. Diets with extruded ingredients had greater digestibilities of DM and N, but fat thickness at the last rib was not affected by treatment. Overall, optimum nutrient digestibility was achieved by feeding extruded diet ingredients, and efficiency of gain was maximized by feeding an extruded blend of sorghum and whole soybeans.

(Key Words: GF, Process, Sorghum, Soybeans, Performance, Digestibility)

Introduction

Extrusion processing is not a new technology; extruders have been used to process human foodstuffs for more than 50 yr. Since those early applications, the high cost of equipment and considerable expertise needed to operate and maintain extruders has restricted their use largely to preparation of human foodstuffs and pet foods. However, there is currently a resurgence of interest in extrusion processing of ingredients and(or) whole diets for swine feeding, largely because of the advent of low-cost extrusion equipment and recognition of specific applications for preparation of specialty protein and starch products (e.g., extruded whole soybeans, soy flour, and soy protein concentrates for baby pig diets.)

In last year's KSU Swine Day Report (page 76), we reported marked improvements in efficiency of growth and nutrient digestibility (5 to 20%) when whole soybeans and sorghum grain were extruded separately and blended into diets for finishing pigs versus feeding ground sorghum-soybean meal-soybean oil-based diets. Reported herein are the results of a second experiment with objectives to determine: 1) if extrusion of a ground sorghum-soybean meal-soybean oil-based diet improves its utilization by finishing pigs and 2) if the positive response to extrusion processing of sorghum and whole soybeans is the same when they are blended and then extruded versus extruded and then blended.

Procedures

One hundred forty-four finishing pigs, with an avg weight of 124 lb, were allotted to one of four dietary treatments based on initial weight, sex, and ancestry. There were nine pigs per 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 × 16 ft) had a two-hole self-feeder and nipple waterer

Treatments were: 1) control diet with ground sorghum, SBM, and soybean oil; 2) diet 1 with the ground sorghum, SBM, and soybean oil blended and then extruded; 3) sorghum and whole soybeans extruded separately and blended; and 4) sorghum and extruded soybeans blended and extruded together. Barrel temperatures during extrusion were 160°F for the sorghum-SBM-soybean oil mixture in diet 2, 140°F for the sorghum and 290°F for the whole soybeans in diet 3, and 150°F for the blend of sorghum and extruded soybeans in diet 4. The sorghum and sorghum-soy mixtures were tempered to 18% moisture before extrusion. Extrusion was in an Insta-Pro® extruder. All diets were formulated to be equal in concentrations of ME and lysine (Table 1), using published values from the NRC, 1988.

Three weeks after initiation of the experiment, chromic oxide was added to the diets (.25%) as an indigestible marker. After a 4-d adjustment period, fecal samples were collected from eight pigs per treatment. The samples were dried, ground, and analyzed for Cr, DM, and N concentrations, so that apparent digestibilities of DM and N could be calculated. Feeding continued until pigs in one pen of a wt block averaged at least 230 lb, at which time all pigs in that wt block were scanned for fat depth at the last rib and removed from the experiment. Final wt was used as a covariate in analyses of the fat depth measurements.

Results and Discussion

Average daily gain was not affected by dietary treatment (Table 2). However, pigs fed diets with extruded ingredients were 14% more efficient (F/G of 3.11 vs 3.61) than pigs fed the ground sorghum-SBM-soybean oil control diet. Although extrusion of the sorghum, SBM, and soybean oil reduced F/G from 3.61 to 3.19, pigs fed that diet were still less efficient than pigs fed diets with extruded sorghum and extruded whole soybeans, especially when sorghum and extruded soybeans were blended and then extruded. All diets were formulated to be in excess of the lysine requirement for finishing pigs and to have the same ME concentration and lysine/ME ratio. Thus, improved feed efficiency for pigs fed extruded sorghum and soybeans indicates that the ME value of sorghum grain is dependent on processing method, and the NRC value for ME of heat processed soybeans is probably too low, at least for dry-extruded whole soybeans.

Apparent digestibilities indicated that extrusion processing of diet ingredients increased DM digestibility by 6% (from 84.1 to 89.5%) and N digestibility by 14% (from 72.3 to 82.3%). Digestibilities of DM and N in diets with the different extrusion treatments were not different ($P>.70$). Last rib fat thickness was not affected by treatment.

In conclusion, results from this experiment support data reported last year, i.e., extrusion of sorghum and whole soybeans improves growth performance and nutrient digestibility in finishing pigs compared to feeding ground sorghum-SBM-soybean oil-based diets. Furthermore, these differences in energy value of extruded sorghum vs ground sorghum and extruded whole soybeans vs SBM and soybean oil warrant re-evaluation of published ME values (such as those found in the NRC for swine) and ME values used in least-cost diet formulation programs.

Table 1. Composition of Diets[a]

Ingredient, %	Control (with SBM)	Extruded soybean diet
Sorghum[b]	80.70	76.09
Soybean meal (48% CP)	14.90	—
Extruded soybeans	—	21.09
Soybean oil	1.50	—
Vit/Min/Antibiotics[c]	2.90	2.82

[a]All diets were formulated to supply .65% lysine, .65% Ca, .55% P, 1.48 Mcal ME/lb of diet, and 2.0 g lysine/Mcal ME (calculated analysis).
[b]Extruded sorghum replaced ground sorghum on a lb for lb basis.
[c]Antibiotic supplied 100 g chlortetracycline per ton of diet.

Table 2. Effect of Extrusion Processing on Nutritional Value of Sorghum, Soybeans, and Soybean Meal for Finishing Pigs

		Extrusion treatment			
Item	Control	Blended sorghum, SBM, soy oil	Sorghum and soybeans	Blended sorghum and soybeans	CV
Growth performance[a]					
ADG, lb[b]	1.97	2.00	1.94	1.99	4.7
ADFI, lb[c]	7.09	6.38	6.17	5.93	5.0
F/G[def]	3.61	3.19	3.18	2.97	2.6
Apparent digestibility					
DM, %[d]	84.1	89.6	89.5	89.5	1.6
N, %[d]	72.3	82.5	81.9	82.5	3.6
Last rib fat thickness, in[b]	1.03	1.05	1.00	1.04	18.5

[a]A total of 144 finishing pigs, avg initial wt of 124 lb, avg final wt of 224 lb. There were nine pigs per pen and four pens per treatment.
[b]No treatment effect (P>.32).
[cd]Control vs extrusion treatments (P<.01, P<.001, respectively).
[e]Extruded sorghum-SBM-soy oil vs extruded sorghum and whole soybean treatments (P<.08).
[f]Sorghum and whole soybeans extruded separately vs sorghum and whole soybeans extruded together (P<.02).

SPACE REQUIREMENTS OF FINISHING PIGS FED TO A HEAVIER WEIGHT (REMOVED INDIVIDUALLY)

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Summary

Space allowances of 6, 8, 10, and 12 ft^2 were evaluated for pigs fed from 120 to 250 lb. The management system used was to remove pigs individually as they reached 250 lb, which provided increasing space per pig. Using this management system, average daily gain, average daily feed intake, and feed efeciency improved linearly with increasing space allowance. Pigs allowed 6 ft^2 gained slower, ate less, and required more feed per lb of gain compared to pigs allowed 8, 10, and 12 ft^2. Pigs permitted 8, 10, and 12 ft^2 were similar in rate of gain, feed consumption, and feed efficiency, suggesting that 8 ft^2 is adequate space for the finishing pig, if pens are topped out as pigs individually reach 250 lb. If pigs are fed to a pen average of 250 lb without removing pigs individually, 10 ft^2 is required to maximize performance, as reported in Report of Progress 581. In this trial, space allowance of 6 ft^2/pig impaired pigs performance from 120 to 200 lb. These results have been observed in previous studies, suggesting that finishing pigs need a minimum of 8 ft^2 in the finishing phase.

(Key Words: G-F, Performance, Space, Heavy Wt.)

Introduction

In the 1989 KSU Swine Day Report of Progress 581, we reported the effect of space allowance for finishing pigs fed to an average pen weight of 250 lb. In those studies, average daily gain and average daily feed intake increased linearly ($P<.05$) as space allowance increased by 2 ft^2/pig from 6 to 12 ft^2/pig. However, pigs permitted 10 or 12 ft^2 of space were similar in performance, indicating that 10 ft^2 was adequate space for feeding hogs to a 250 lb average pen weight.

This study was conducted to evaluate 6, 8, 10, and 12 ft^2 per finishing pig with pigs fed to a heavier market weight but removed individually as they reached 250 lb when weighed weekly. This management procedure is similar to that used by swine producers who stock pens at 6 to 7 ft^2 and then remove pigs as they reach market weight.

Procedures

Pigs were allotted to one of four replicated treatments (6, 8, 10, or 12 ft^2/pig space allowance) on the basis of weight, litter and sex. Feeder and waterer space was subtracted from the total pen square footage to determine allowable space per pig. Pigs were housed in a modified open front building with 16 ft long pens adjusted for width to develop the desired square footage. Each pen had 8 ft of concrete slats and 8 ft of solid floor. Each pen housed 15 pigs and was equipped with one nipple waterer and a round feeder. All pigs were fed ad libitum a sorghum grain-soybean meal fortified diet that had a calculated analysis of 14.7% crude protein, .65% lysine, .65% calcium, and .50% phosphorous. No antibiotic was added to the finisher ration.

Pigs were weighed biweekly for the first 42 d of the trial and weekly thereafter. Pigs were removed each week as they individually reached 250 lb. When at least 50% of the pigs had been removed from the pen individually, the remainder of the pen of pigs were fed to an average group weight of 250 lb, at which time the experiment was terminated.

Results and Discussion

The effect of space allowance on pigs fed to a heavier weight are shown in Table 1. During the first 42 d of the trial, those pigs allowed 10 and 12 ft^2 of space were significantly more efficient (P<.05) than those pigs permitted 6 ft^2. Pigs allowed 8 ft^2 grew slightly faster and were more efficient than those permitted 6 ft^2; however, the difference was not significant. At the end of 42 d on trial, the average weight of the pigs was approximately 198 lb, suggesting that 6 sq ft was not enough space for pigs as they grew from 120 to 200 lb. The impaired performance observed for this weight pig was also reported in 1989 Report of Progress 581 for pigs permitted only 6 ft^2 of space/pig.

In the overall trial, average daily gain and average daily feed intake increased linearly (P<.05) as pigs were permitted more space. In addition, feed/gain ratio improved linearly (P<.05) with more space allowance per pig. Average daily gain was significantly reduced (P<.05) for those pigs permitted 6 ft^2 when compared to those allowed 8, 10, or 12 ft^2. Average daily feed intake was significantly less (P<.05) and F/G was significantly poorer (P<.05) for pigs permitted 6 ft^2 compared to those permitted 12 ft^2.

Average daily gain, average daily feed intake, feed efficiency, and days on test were similar for pigs allowed 8, 10, or 12 ft^2, suggesting that 8 ft^2 is adequate space if the pigs are removed individually as they reach 250 lb.

Table 1. Effect of Space Allowance on Performance of Finishing Pigs Fed to 250 lb. (Removed Individually)

	Space allowance, ft^2/pig			
Item	6	8	10	12
Day 1 - 42[a]				
Avg daily gain, lb[b]	1.77[c]	1.91[cd]	1.96[d]	2.02[d]
Avg daily feed intake, lb	5.99	6.18	6.16	6.24
Feed/gain[b]	3.38[c]	3.25[cd]	3.15[d]	3.09[d]
Overall				
Avg final wt, lb	251.7	251.3	254.9	253.7
Avg no. d on feed	79.2	72.1	73.3	71.0
Avg daily gain, lb[b]	1.70[c]	1.86[d]	1.88[d]	1.96[d]
Avg daily feed intake, lb[b]	6.00[c]	6.26[cd]	6.36[cd]	6.40[d]
Feed/gain[b]	3.54[c]	3.37[cd]	3.39[cd]	3.26[d]

[a]Fifteen pigs per pen with four pens/treatment; avg initial wt = 121 lb.
[b]Linear effect of space allowance (P<.05).
[cd]Means on same line with diferent superscripts difer significantly (P<.05).

EFFECTS OF PORCINE SOMATOTROPIN DOSAGE AND LYSINE LEVEL ON GROWTH PERFORMANCE OF GROWING PIGS

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Summary

Eighty crossbred barrows initially weighing 70.5 lb were used in a 5 wk trial to determine the optimum dosage of porcine somatotropin (pST) required to promote maximum growth response in growing pigs fed diets containing either 1.0 or 2.0% lysine. Pigs received a daily injection of placebo or 2, 4, or 8 mg pST in combination with one of two experimental diets containing either 1.0 or 2.0% dietary lysine. Increasing the dosage of pST of pigs fed both diets resulted in an increase in average daily gain (ADG), a reduction in average daily feed intake (ADFI), and an improvement in feed conversion (F/G). Average backfat, calculated from ultrasonic measurements at the first rib, last rib, and last lumbar vertebra, was reduced in pigs fed both diets as pST dosage increased. Serum pST increased and urea nitrogen decreased for pigs fed both diets as pST dosage increased. The improvement in ADG and F/G of pigs fed both diets was quadratic, indicating that a plateau was achieved between 4 and 8 mg/d pST administration. The serum urea nitrogen response appeared to plateau near 8 mg/d. The combination of these response criteria indicates that the dosage required for maximum response is about 7 mg/d pST, whereas the more optimum level of pST administration may be about 5 mg/d for growing pigs fed diets containing 1.0 or 2.0% lysine.

(Key Words: GF, Repartition, Performance, Lysine.)

Introduction

The effects of porcine somatotropin (pST) on growth performance of finishing swine have been much greater than those seen in growing pigs. Increased levels of dietary lysine improved growth performance of growing pigs injected with pST by only 10% in an experiment reported in the 1990 Swine Day, Report of Progress 610. Pigs in that experiment were injected with either a placebo or 3 mg/d pST. The optimum dosage of pST has not been previously determined for the growing pig. Therefore, this experiment was designed to determine the dosage of pST administration required to promote maximum response in growing pigs fed either 1.0 or 2.0% dietary lysine.

Procedures

Eighty crossbred barrows initially weighing 70.5 lb were allotted by weight and ancestry to one of eight experimental treatments. Treatments included two corn-corn gluten meal-soybean meal diets (Table 1) formulated to contain either 1.0 or 2.0% lysine in combination with injections of placebo or 2, 4, or 8 mg/d pST. L-lysine HCl was substituted for corn in the diet containing 2.0% lysine. Diets were formulated to provide 200% of NRC recommended levels for all other essential amino acids, vitamins, and minerals. Pigs were allowed ad libitum access to feed and water. There were two pigs per pen and five pens per treatment. Pigs were housed in a modified open front building with solid concrete floors. All pigs and feeders were weighed weekly for calculations of average daily gain (ADG). average daily feed intake (ADFI), and feed conversion (F/G). Blood samples were obtained on d 14 and d 28 for analysis of serum pST and urea nitrogen. At the

[1]Pitman-Moore, Inc., Terre Haute, IN 47808.

end of the 5 wk growth trial, average backfat thickness, measured ultrasonically at the first rib, last rib, and last lumbar vertebra, was determined.

Table 1. Composition of Diets

	Dietary Lysine, %	
Ingredient	1.0	2.0
Corn	55.31	54.03
Soybean meal (48% CP)	24.65	24.65
Corn gluten meal (60% CP)	8.95	8.95
Soybean oil	5.00	5.00
Monocalcium phosphate (21% P)	3.02	3.02
Limestone	1.38	1.38
L-lysine HCl	——	1.28
L-threonine	.09	.09
Salt	.30	.30
Vitamin premix	.50	.50
Trace mineral premix	.20	.20
Antibiotic[a]	.50	.50
Copper sulphate	.05	.05
Selenium premix	.05	.05
Total	100.00	100.00
Calculated Analysis, %		
CP	22.1	22.1
Lysine	1.00	2.00
Ca	1.20	1.20
P	1.10	1.10

[a]Each lb of antibiotic contained 10 g chlortetracycline, 10 g sulfathiazole, and 5 g peni-

Results and Discussion

During the first 2 wk of the trial, there was no effect of pST dosage on average daily gain (ADG) for pigs fed 1.0% dietary lysine (Table 2). However, there was a linear reduction (P<.01) in average daily feed intake (ADFI), which resulted in a linear and quadratic improvement in feed conversion F/G as pST dosage increased. Porcine somatotropin dosage had no effect on ADFI of pigs fed diets containing 2.0% dietary lysine. Increasing the dosage of pST from 0 to 8 mg/d resulted in increased ADG (linear, P<.01) and improved F/G (linear, P<.01 and quadratic, P<.05) of pigs fed 2.0% lysine. Increasing the dietary lysine level of pigs from 1.0 to 2.0% resulted in an improvement in F/G (P<.05).

Pigs fed 1.0% dietary lysine for the total 5 wk trial had increased ADG (linear, P<.01 and quadratic, P<.05), reduced ADFI (linear, P<.01), and improved F/G (linear, P< .01 and quadratic, P<.05) as pST dosage increased. Increasing the pST dosage also reduced average backfat (linear, P<.01) of pigs fed 1.0% lysine diets.

During the 5 wk trial, pigs injected with an increasing pST dosage and fed diets with 2.0% lysine had greater ADG (linear, P<.01 and quadratic, P<.05), reduced ADFI (linear, P<.01), and improved F/G (linear, P<.01 and quadratic, P<.05). The quadratic nature of the response for ADG and F/G of pigs to pST dosage indicates that the dosage of pST required to achieve maximum growth response of pigs fed 2.0% lysine diets was achieved and was between 4 and 8 mg/d. Increasing pST dosage of pigs fed 2.0% dietary lysine resulted in a decrease (linear, P<.01) in average backfat.

As expected, increasing the pST dosage resulted in a linear increase (P<.01) in serum pST of pigs fed both the 1.0 and 2.0% lysine diets. The reduction in wk 2 serum urea nitrogen of pigs fed the 2.0% lysine diet compared to those fed the 1.0% lysine diet suggests that the dietary amino acids metabolized by the pigs were better utilized, which is an indication that lysine was limiting in those pigs fed the 1.0% lysine diet. The improvement in F/G (P<.05) of pigs fed the diet containing 2.0% lysine compared to those fed the 1.0% lysine diet also supports the theory of an improvement in utilization of dietary amino acids. The linear (P<.01) and quadratic (P<.05) reduction in serum urea nitrogen as pST dosage was increased suggests that there was better utilization and less deamination of the dietary amino acids. A statistical analysis indicated that the response in serum urea nitrogen was maximized near 8 mg/d.

The improvements in growth performance (ADG and F/G) indicate that growing pigs fed 1.0 and 2.0% dietary lysine require between 4 and 8 mg/d pST administration for maximum response. The point of inflection for ADG and F/G is approximately 5 mg/d. The level of pST required to optimize serum urea nitrogen is near 8 mg/d. The point of inflection for serum urea nitrogen is approximately 7 mg/d pST administration. The dosage required for maximum response in serum urea nitrogen was higher than the dosage required for maximum growth performance. The dosage of pST required for optimum growth performance of growing pigs fed 1.0 or 2.0% dietary lysine was determined to be near 5 mg/d.

Table 2. Performance, Carcass, and Blood Characteristics of Pigs Fed 1.0 or 2.0% Dietary Lysine and Injected with Porcine Somatotropin (pST)

	Lysine, %								
	1.0				2.0				
	pST Dosage, mg/d				pST Dosage, mg/d				
Characteristics	0	2	4	8	0	2	4	8	CV
Growth Performance[a]									
Wk 0-2									
ADG, lb[b]	2.05	2.35	2.14	2.18	2.14	2.28	2.36	2.54	11.1
ADFI, lb[c]	4.58	4.67	4.36	3.86	4.65	4.30	4.08	4.26	8.5
F/G[bcde]	2.23	1.99	2.13	1.77	2.17	1.88	1.73	1.68	10.1
Wk 0-5									
ADG, lb[bcf]	2.01	2.29	2.41	2.32	2.11	2.25	2.36	2.42	6.2
ADFI, lb[bc]	5.47	5.63	5.24	4.93	5.71	5.41	5.07	4.80	5.5
F/G[bcef]	2.72	2.46	2.19	2.13	2.72	2.40	2.15	1.99	5.5
Carcass and Blood Parameters[g]									
Average backfat, in[bch]	.32	.33	.29	.26	.34	.30	.28	.25	10.6
Wk 2 serum urea nitrogen, mg/dl[bcdef]	40.8	33.2	23.8	24.2	42.8	27.5	19.2	13.5	14.0
Wk 4 serum urea nitrogen, mg/dl[bcef]	42.1	34.0	28.8	23.8	43.3	33.3	24.9	19.9	10.9
Wk 2 serum pST, ng/ml[bc]	3.60	8.59	14.37	23.27	2.16	10.23	14.11	20.21	18.9
Wk 4 serum pST ng/ml[bc]	3.17	7.98	13.49	18.30	3.89	7.41	13.41	20.15	23.6

[a]A total of 80 pigs initially weighing 70.5 lb, 2 pigs/pen, 5 pens/treatment.
[b]Pigs fed 2.0% lysine, linear response to pST (P<.01).
[c]Pigs fed 1.0% lysine, linear response to pST (P<.01).
[d]Lysine effect (P<.05).
[e]Pigs fed 2.0% lysine, quadratic response to pST (P<.05).

[f]Pigs fed 1.0% lysine, quadratic response to pST (P<.05).
[g]Serum samples obtained 4 h post-injection, 3 h post-prandial.
[h]An average of ultrasonic measurements at the first rib, last rib, and last lumbar vertebra at the end of the 5 wk trial.

EFFECTS OF DAILY PORCINE SOMATOTROPIN ADMINISTRATION ON THE LYSINE REQUIREMENT OF GROWING PIGS [1]

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Summary

One-hundred twenty crossbred barrows initially weighing 68.7 lb were used to determine the lysine requirement of growing pigs injected with 5 mg/d porcine somatotropin (pST) during a 5-wk growth trial. Pigs received one of six levels of dietary lysine (.7, 1.1, 1.5, 1.9, 2.3, or 2.7%) and were injected daily with either 5 mg pST or placebo. During the 5 wk trial, pST-injected pigs had increased average daily gain (ADG), decreased average daily feed intake (ADFI), and improved feed conversion (F/G) compared with placebo-injected pigs. With increasing dietary lysine, ADFI of pigs injected with both pST and placebo was reduced. Pigs injected with pST had improved ADG as dietary lysine increased to 1.5% and improved F/G as dietary lysine increased to 1.9%. Dietary lysine had no effect on ADG or F/G of placebo-injected pigs. Pigs injected with pST had improved average backfat, tenth rib fat depth, and longissimus area compared to placebo-injected pigs. Tenth rib fat depth of both placebo- and pST-injected pigs was reduced as dietary lysine increased. Longissimus area of pST-injected pigs improved as dietary lysine increased to 1.5%. The improvements in ADG, ADFI, F/G, and longissimus area of pST-injected pigs indicate that the dietary lysine requirement of growing pigs injected with 5 mg/d pST is 1.5 to 1.9%.

(Key Words: GF, Repartition, Performance, Carcass, Lysine.)

Introduction

Administration of porcine somatotropin (pST) to growing pigs has been shown to be an effective means of improving growth performance and carcass characteristics. The dosage of pST required to elicit the greatest response has been found to be greater in growing pigs than in finishing pigs. The lysine requirement of finishing pigs injected daily with pST has been determined to be about twice that recommended by the NRC. The lack of response in experiments using growing pigs may be because the dosage of pST or the dietary lysine was inadequate to provide for the maximum response. This experiment was designed to determine the lysine requirement of growing pigs injected with 5 mg/d pST.

Procedures

One-hundred twenty crossbred barrows initially weighing 68.7 lb were allotted by weight and ancestry to one of 12 experimental treatments. Treatments included six diets (Table 1) formulated to contain either .7, 1.1, 1.5, 1.9, 2.3, or 2.7% lysine in combination with daily injections of either placebo or 5 mg pST. A mixture of soybean meal and L-lysine HCl were substituted for corn to increase the dietary lysine from .7 to 2.7%. Diets were formulated to contain 250% of NRC recommendations for all other essential amino acids using synthetic L-threonine, L-isoleucine, L-tryptophan, L-valine, and DL-methionine. Vitamins and minerals were included in diets to provide 200% of NRC recommended levels. Pigs were allowed ad libitum access to feed and water. There were two pigs per pen and five pens per treatment. Pigs were housed in a fully enclosed, environmen-

[1]We would like to acknowledge BioKyowa, St, Louis, MO for the donation of synthetic amino acids and Pitman-Moore, Inc., Terre Haute, IN in support of this research.

tally regulated building with a totally slatted floor. All pigs and feeders were weighed weekly, and all feed additions were recorded for calculations of average daily gain (ADG), average daily feed intake (ADFI), and feed conversion (F/G). At the end of the 5 wk experiment, six pigs from each treatment were slaughtered for determination of carcass characteristics.

Results and Discussion

During the first 2 wk of the experiment, ADG increased, ADFI decreased, and F/G improved for pigs injected with pST (P<.01) compared to pigs injected with placebo (Table 2). Average daily gain of pigs injected with pST increased (P<.05) with increasing levels of dietary lysine up to 1.9%, whereas ADG of pigs injected with placebo increased up to 1.5% dietary lysine. Feed intake of both placebo- (P<.05) and pST-injected pigs (P<.01) decreased as dietary lysine levels increased. This resulted in improved F/G of pST-treated pigs up to 1.9% dietary lysine and of placebo-injected pigs up to 1.5% dietary lysine (P<.01).

During the overall 5 wk trial, pigs injected with pST had increased ADG, reduced ADFI, and improved F/G compared to placebo-injected pigs (P<.01). Injection of pigs with pST also resulted in reduced average backfat, reduced 10th rib fat depth, and increased longissimus area compared to injection with placebo (P<.01).

Increasing the dietary lysine level of pST-injected pigs resulted in an increase (P<.05) in ADG up to a lysine level of 1.5%, a linear (P<.02) reduction in ADFI, and an improvement (P<.05) in F/G to between 1.5 and 1.9% dietary lysine. Carcasses of pST-injected pigs had less (P<.05) backfat as dietary lysine was increased to 1.5% and a linear reduction (P<.02) in 10th rib fat depth with increasing levels of dietary lysine. Longissimus area of pST-injected pigs increased (P<.05) as dietary lysine was increased to 1.5 and 1.9%.

Table 1. Composition of Diets

Increasing the dietary lysine had no effect on ADG, F/G, or average backfat of placebo-injected pigs. Pigs injected with placebo had a linear reduction (P<.02) in ADFI and 10th rib fat depth with increasing levels of dietary lysine. The longissimus area of placebo-injected pigs increased as dietary lysine increased up to a level of 1.1%.

The only trait indicating that the dietary lysine level of placebo injected pigs was inadequate was the increase in longissimus area up to 1.1% dietary lysine. Thus, the current NRC recommendation of .75% lysine closely approximates the requirement of the placebo-injected pigs in this experiment. The lysine intake of placebo-injected pigs fed diets containing .7 and 1.1% lysine was 14 and 21 g/d, respectively. Because of the large differences in dietary lysine in this experiment, it is possible that a response occurred in placebo-injected pigs between .7 and 1.1% and was not detected. The improvement in growth performance of pST-treated pigs with increasing levels of dietary lysine up to 1.5% (ADG) or 1.9% (ADFI and F/G) along with the increase in longissimus area up to 1.9% indicates that the lysine requirement of growing pigs injected with 5 mg/d pST is between 1.5 and 1.9%. The lysine intake of pST-injected pigs was 24 and 28 g/d for pigs fed diets containing 1.5 and 1.9% lysine, respectively. These recommendations represent a 200 to 250% increase in the lysine requirement of pST-injected pigs compared to the NRC recommendation of .75% lysine for 44 to 110 lb pigs on the basis of dietary percentage. The NRC recommendation for lysine is 14.25 g/d. Comparing the lysine requirement of pST-injected pigs in g/d, the increase is between 170 and 195% of the NRC recommendation.

	Percentage Lysine					
Ingredient	.7	1.1	1.5	1.9	2.3	2.7
Corn	59.95	52.15	44.15	36.05	27.75	19.45
Corn gluten meal (60% CP)	20.00	20.00	20.00	20.00	20.00	20.00
Soybean meal (48% CP)	5.00	13.20	21.40	29.60	37.80	46.10
Menhaden fishmeal	4.00	4.00	4.00	4.00	4.00	4.00
Soybean oil	5.00	5.00	5.00	5.00	5.00	5.00
Monocalcium phosphate(21% P)	2.85	2.70	2.56	2.42	2.28	2.13
Limestone	1.09	1.05	1.02	.99	.95	.92
L-lysine HCl	——	.21	.42	.63	.84	1.05
Vitamin premix	.50	.50	.50	.50	.50	.50
Antibiotic[a]	.25	.25	.25	.25	.25	.25
Salt	.30	.30	.30	.30	.30	.30
Trace mineral premix	.20	.20	.20	.20	.20	.20
Copper sulfate	.05	.05	.05	.05	.05	.05
Selenium premix	.05	.05	.05	.05	.05	.05
L-threonine	.35	.22	.10	——	——	——
L-isoleucine	.21	.07	——	——	——	——
L-tryptophan	.15	.09	.04	——	——	——
L-valine	.04	——	——	——	——	——
DL-methionine	.06	——	——	——	——	——
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analyses						
CP, %	22.16	25.55	28.97	32.38	35.79	39.20
Lysine, %	.7	1.1	1.5	1.9	2.3	2.7
Ca, %	1.20	1.20	1.20	1.20	1.20	1.20
P, %	1.00	1.00	1.00	1.00	1.00	1.00
ME, Kcal/lb	1552	1557	1559	1559	1558	1556

[a]Each lb of antibiotic contained 10 g chlortetracycline.

Table 2. Performance and Carcass Characteristics of Pigs Injected Daily with Placebo (0) or pST (5 mg)

	Porcine Somatotropin (pST), mg/d												
	0						5						
	Lysine, %						Lysine, %						
Item	.7	1.1	1.5	1.9	2.3	2.7	.7	1.1	1.5	1.9	2.3	2.7	CV
Growth Performance[a]													
Wk 0-2													
ADG, lb[bcd]	1.56	1.76	2.01	1.66	1.62	1.64	1.48	2.05	2.11	2.18	1.85	1.99	14.4
ADFI, lb[bef]	3.75	3.75	3.38	3.45	3.16	3.21	3.11	3.44	3.09	2.96	2.66	2.81	9.6
F/G[bcdef]	2.41	2.15	1.68	2.11	1.95	1.96	2.11	1.68	1.47	1.38	1.48	1.45	10.2
Wk 0-5													
ADG, lb[bdg]	1.76	1.81	1.84	1.75	1.68	1.71	1.62	2.13	2.20	2.10	2.00	1.92	9.4
ADFI, lb[bef]	4.30	4.19	4.10	4.13	3.72	3.93	3.74	3.88	3.54	3.28	3.21	3.09	7.3
F/G[bdfg]	2.44	2.33	2.27	2.37	2.21	2.32	2.30	1.82	1.61	1.56	1.61	1.61	7.0
Carcass Characteristics[h]													
Slaughter wt, lb	130.8	129.7	132.7	131.0	128.7	126.0	124.8	146.0	141.7	141.5	136.2	138.5	
Average backfat, in[bdfi]	.93	.93	.88	.89	.85	.84	.83	.72	.63	.63	.68	.66	15.6
Fat depth, 10th rib, in[bef]	.85	.82	.72	.82	.64	.68	.65	.52	.46	.43	.44	.37	18.6
Longissimus area, sq in[bdf]	3.12	3.51	3.49	3.24	3.54	3.36	3.13	4.13	4.42	4.45	4.09	4.27	13.0

[a]A total of 120 pigs initially weighing 68.7 lb, 2 pigs/pen, 5 pens/treatment.
[b]pST effect (P<.01).
[c]placebo injected pigs, quadratic response to lysine (P<.05).
[d]pST injected pigs, quadratic response to lysine (P<.05).
[e]placebo injected pigs, linear response to lysine (P<.02).
[f]pST injected pigs, linear response to lysine (P<.02).
[g]Lysine X pST (P<.05).
[h]A total of 72 pigs, 6 pigs/treatment.
[i]Mean of measurements taken over the first rib, the last rib and the last lumbar vertebra.

THE INFLUENCE OF DIETARY THREONINE ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF PST-TREATED FINISHING PIGS [1]

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Summary

Eighty crossbred barrows (initial wt = 131 lb) were utilized to determine the dietary threonine requirement of finishing pigs injected with porcine somatotropin (pST). Barrows were injected daily in the extensor muscle of the neck with either 4 mg pST or a placebo and fed diets containing either .45, .55, .65, or .75% threonine. All other amino acids, vitamins, and minerals were calculated to be at least double current requirements for finishing pigs so as not to limit performance. Pigs were housed in an open-sided building with two pigs per pen and five replications of the eight treatments. Feed and water were provided ad libitum. When the mean weight of the two pigs per pen averaged 235 +/- 5 lb, pigs were slaughtered and carcass data collected. Porcine somatotropin-treated pigs had greater average daily gain (ADG), reduced daily feed intake (ADFI), and improved feed efficiency (F/G) compared to control pigs. A dietary threonine × pST interaction was observed for ADG. Control pigs exhibited no improvement in ADG with increasing dietary threonine. However, pST-treated pigs had a 22% increase in ADG as dietary threonine increased from .45 to .65%. Increasing dietary threonine resulted in increased ADFI, but had no effect on F/G. Average backfat thickness, tenth rib fat depth, and kidney fat were reduced by pST administration. Longissimus muscle area and trimmed ham and loin weights were greater in pST-treated pigs. Dietary threonine tended to reduce average backfat thickness but had no effect on other carcass criteria measured. These results suggest that growth rate of pST-treated pigs is increased by dietary threonine level compared to control pigs. This interactive response between pST and threonine was not observed in feed efficiency or carcass criteria measured; however, there were numerical trends similar to those observed for daily gain.

(Key Words: G-F, Performance, Threonine, Repartition, Carcass.)

Introduction

Porcine somatotropin (pST) is an effective modifier of swine growth, feed utilization, and carcass criteria. However, the magnitude of response to pST administration has been determined to be interactively linked with the nutritional allowances of the pig. Research at Kansas State University has established that the response of finishing pigs to pST administration is directly dependent on the dietary lysine level. The lysine requirement of a pST-treated pig is approximately 25 to 30 g/d compared to the 18 to 20 g/d for a non-pST-treated finishing pig. Based on these data, we hypothesize that other amino acid requirements may be altered by pST administration. In addition, the extent that one amino acid requirement is changed in proportion to another may be altered if growth rate is significantly altered (i.e., a change in amino acid ratio). Therefore, the objective of this experiment was to determine the influence of dietary threonine on growth performance and carcass characteristics of control and pST-treated finishing pigs.

[1]The Authors would like to thank BioKyowa and Nutri-Quest for donating amino acids and partial funding of this experiment.

[2]Pitman-Moore, Inc. Terre Haute, IN 47808.

Procedures

Eighty crossbred barrows averaging 131 lb were allotted on the basis of weight and ancestry to one of eight experimental treatments. Treatments included either a daily injection of 4 mg pST or a placebo in combination with a pelleted milo-peanut meal diet containing either .45, .55, .65, or .75% threonine provided by L-threonine (Table 1). All other amino acids, vitamins, and minerals were calculated to be at least double current requirements for finishing pigs so as not to limit performance (Table 2). Pigs were housed in an open-sided building with two pigs per pen and five replicate pens per treatment. When the mean weight of the two pigs per pen averaged 230 +/- 5 lb, pigs were slaughtered and carcass data collected.

Table 1. Composition of Basal Diet

Ingredient	%
Sorghum	65.04
Peanut meal, solvent	20.03
Soybean oil	7.00
Monocalcium phosphate	3.31
Limestone	1.13
L-lysine HCl	1.47
Vitamin premix	.50
Trace mineral premix	.20
DL-methionine	.34
Salt	.25
L-isoleucine	.21
L-tryptophan	.06
Selenium premix[a]	.05
Sucrose/threonine[b]	.40
Total	100.00

[a]Provided .3 ppm Selenium.
[b]Sucrose was replaced by threonine to provide levels of .55,.65, and .75%.

Data were analyzed as a 2 × 4 factorial arrangement with pST and dietary threonine as main effects. Average backfat, longissimus muscle area (10th thoracic vertebrae), and length were all adjusted to a constant weight of 230 lb using NPPC (1988) guidelines. Other carcass criteria were adjusted using final weight as a covariate.

Table 2. Chemical Analysis of Basal Diet

Item	%
Crude Protein	18.63
Ca[1]	1.10
P[1]	1.00
Essential Amino Acids	
Threonine	0.45
Arginine	1.31
Cystine	0.23
Histidine	0.38
Isoleucine	0.78
Leucine	1.48
Lysine	1.49
Methionine	.49
Phenylalanine	.82
Tyrosine	.59
Tryptophan	.21
Valine	.73

Results and Discussion

Porcine somatotropin-treated pigs had greater average daily gain (ADG; P<.05) than control pigs (Table 3). In addition, increasing dietary threonine level increased ADG (P<.06); however the greatest response was observed for pST-treated pigs. This resulted in a pST × threonine interaction (P<.10) because control pigs exhibited no change in ADG, but pST-treated pigs had a 22% increase in ADG as threonine increased from .45 to .65%. Average daily feed intake (ADFI) was reduced in pST-treated pigs (P<.10); however, pST-treated pigs fed the diet containing .65% threonine unexplainably had the greatest feed intake of any treatment group. Porcine somatotropin-treated pigs were more efficient than control pigs (P<.05); however, there was no improvement with increasing threonine level. Because of the high feed intake, pST-treated pigs fed the .65% threonine diet had the poorest feed efficiency among pST-treated pigs.

Because all pigs were slaughtered when their mean weight was 235 lb, there were no differences in hot carcass weight or skinned dressing percent. Average backfat thickness and 10th rib fat depth were reduced (P<.05) for pST-treated pigs. Longissimus muscle area was increased for pST-treated pigs (P<.05) and tended to increase (8%) with increasing threonine level compared to control pigs. Weight of kidney fat was reduced (P<.05) in pST-treated pigs compared to control pigs. Within pST-treated pigs, there was a 30% reduction in kidney fat as threonine level increased from .45 to .65%. Trimmed loin and ham weights were greater in pST-treated pigs. Control pigs had no changes in ham or loin weight in response to increasing dietary threonine; however, pST-treated pigs tended (P>.10) to have numerically heavier ham and loin weights as threonine increased.

These results suggest that growth rate of pST-treated pigs is increased by dietary threonine level compared to control-treated pigs. This interactive response between pST and threonine was not observed in feed efficiency or carcass criteria measured; however, there were numerical trends similar to those observed for daily gain. Based on results of previous research, pST administration may increase the dietary lysine and threonine requirements of finishing pigs. However, there appears to be a much greater increase in the pig's lysine requirement compared to threonine. Therefore, pST administration may change the optimal amino acid ratio. This change is similar to the changes in amino acid ratios between starter pigs, which have a relatively wide lysine to threonine ratio (dietary threonine level is approximately 57% of dietary lysine level) compared to finishing pigs (dietary threonine level is approximately 66% of lysine level).

Table 3. Influence of Dietary Threonine and pST on Growth Performance of Finishing Pigs [a]

	Threonine, %				
Item	.45	.55	.65	.75	CV
ADG, lb.[bcd]					
Control	1.94	1.86	1.97	1.98	10.5
4 mg pST	2.00	2.23	2.44	2.01	
ADFI, lb.[ce]					
Control	5.55	5.25	5.78	5.32	13.4
4 mg pST	4.48	5.08	6.07	4.53	
F/G[b]					
Control	2.85	2.82	2.91	2.69	9.7
4 mg pST	2.24	2.25	2.50	2.25	

[a]A total of 80 pigs (five observations per treatment), average initial weight 131 lb, average final wt 235 lb.
[b]PST effect (P<.05).
[c]Quadratic effect of threonine (P<.05).
[d]PST × threonine interaction (P<.10).
[e]PST effect (P<.10).

Table 4. The Influence of pST and Dietary Threonine on Carcass Measurements [a]

	Threonine, %				
Item	.45	.55	.65	.75	CV
Hot carcass wt, lb					
Control	148.8	151.6	148.1	149.4	2.5
4 mg pST	149.4	145.4	150.7	153.1	
Skinned dressing percentage					
Control	62.9	64.2	62.6	63.2	4.2
4 mg pST	63.3	61.7	63.9	64.9	
Backfat thickness, in. [bc]					
Control	1.68	1.59	1.62	1.74	15.9
4 mg pST	1.35	1.18	1.23	1.25	
Tenth rib fat depth, in. [b]					
Control	1.20	1.17	1.16	1.19	22.7
4 mg pST	.97	.79	.90	.78	
Longissimus muscle area, in. [b]					
Control	5.27	5.10	4.98	5.02	15.6
4 mg pST	6.09	5.97	6.34	6.56	
Carcass length, in.					
Control	31.52	31.63	32.05	31.47	2.6
4 mg pST	32.51	32.52	31.87	30.86	
Kidney fat, g [b]					
Control	1457.0	1366.0	1474.0	1458.0	25.7
4 mg pST	1195.0	943.0	841.0	871.0	
Trimmed loin wt, lb. [b]					
Control	15.52	16.15	15.71	14.97	8.4
4 mg pST	17.22	16.97	17.84	17.79	
Trimmed ham wt, lb. [b]					
Control	16.09	16.20	15.60	15.84	9.3
4 mg pST	17.28	16.96	18.01	18.03	

[a] A total of 80 pigs, average initial wt 131 lb, average final wt 235 lb. Means represent 10 observations/treatment.
[b] PST effect ($P<.05$).
[c] Quadratic effect of threonine ($P<.10$).

THE INTERACTIVE EFFECTS OF pST AND SALBUTAMOL ON THE LYSINE REQUIREMENT OF FINISHING PIGS[1]

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Summary

A metabolism study was conducted to evaluate the interactive effects of daily pST injections and the β-agonist salbutamol on the lysine requirement of finishing pigs based on nitrogen retention. Sixteen finishing pigs (137 lbs initially) were exposed to one of four biological treatments for 32 d. These treatments were: 1) non-treated control; 2) 4 mg/d pST; 3) 2.75 ppm of dietary salbutamol; 4) both salbutamol and pST. Pigs were kept on the same biological treatment and offered one of four diets for an 8 d period in a Latin square arrangement. Diets were formulated to contain .8, 1.2, 1.6, and 2.0% dietary lysine, the assumed first-limiting amino acid. Pigs were acclimated to each diet for a 4 d period, after which feces and urine were collected for 4 d to evaluate nitrogen retention. Results indicate that the β-agonist salbutamol increased the daily feed consumption, daily gain, and the efficiency of gain; whereas pST injection reduced feed consumption and increased efficiency of gain. No interaction occurred between pST and salbutamol for percent nitrogen retention; however, pigs injected with pST and fed salbutamol had a higher daily nitrogen retention because of an increased nitrogen intake and improved nitrogen utilization. Pigs treated with pST had leaner carcasses with a higher percent muscle than non-treated controls or pigs fed salbutamol. These data suggest that pigs injected with pST have a dietary lysine requirement between 1.2 and 1.6%, whereas those fed salbutamol have a requirement similar to that of non-treated pigs, which may be confounded with increased daily feed intake. Pigs treated with both pST and salbutamol appear to have a lysine requirement slightly lower than that of pigs injected with pST alone, which appears to be due to increased feed intake.

(Key Words: G-F, Lysine, Repartitioning, Hormone.)

Introduction

Recombinant porcine somatotropin (pST) has been shown to increase the dietary lysine requirement of finishing pigs. This is primarily a consequence of two phenomena. First, pigs injected daily with pST have significantly lower feed intakes than non-treated pigs; secondly, pST-treated pigs have faster rates of protein deposition. The combination of reduced feed consumption and increased net protein deposition leads to much higher requirement for lysine when expressed on a daily basis and when represented as a percent of the diet. The β-agonist salbutamol has been shown to improve longissimus muscle area and daily gains when included at 2.75 ppm of the diet. No data have been reported on the lysine requirement of pigs fed diets containing salbutamol; thus, establishing such a requirement serves to enhance our understanding of the growth-promoting effects of the β-agonist. Therefore, it was the objective of this study to evaluate the interactive effects of pST and salbutamol on the lysine requirement of finishing pigs.

[1]Appreciation is expressed to Pitman-Moore, Terra Haute, IN, 47808 for supplying the porcine somatotropin used in this research.

Procedures

Sixteen pigs were randomly assigned to one of the four biological treatments imposed during the 32 d study. These treatments were: 1) non-treated control; 2) 4 mg/d pST; 3) 2.75 ppm of dietary salbutamol; 4) both 2.75 ppm salbutamol and 4 mg/d pST. Pigs received the same biological treatment throughout the study to avoid potential residual effects. The trial was further subdivided into four periods, each lasting 8 days. In the 8 d periods, pigs were fed each of four diets (Table 1) formulated to contain .8, 1.2, 1.6, and 2.0% lysine, the assumed first-limiting amino acid. During the first 4 days of each period, pigs were acclimated to the assigned diet, and during the subsequent 4-day period, both feces and urine were collected for calculation of daily nitrogen retention, percent nitrogen retention, apparent biological value of nitrogen, apparent nitrogen digestibility, and apparent dry matter digestibility. Percent nitrogen in the samples was determined using the Kjeldahl procedure for nitrogen determination. Ferric oxide (.1%) was included to mark the start and stopping points for feces collection. Data were analyzed as a split-plot design with biological treatments as whole plots and lysine levels as subplots. Pigs were assigned to diets by period according to a 4 × 4 Latin square design. Pigs were fed twice daily at a level equal to or exceeding their maximal intake during the previous 12 hour period, to allow ad libitum access to feed and water. After the last pig passed red marker, all pigs were slaughtered and carcass criteria measured. Measured performance criteria included: average daily gain (ADG), average daily feed intake (ADFI), and feed/gain (F/G).

Results and Discussion

Interaction means for the performance data are presented in Table 2, though no interactions between treatments for performance criteria were detected. Main effect means demonstrate that salbutamol (treatments 2 and 4 vs treatments 1 and 3) increases ADG (2.51 vs 2.02 lb, respectively; P<.01) and ADFI (6.76 vs 6.23 lb, respectively; P<.04) and improves F/G (2.79 vs 3.68, respectively; P<.01). Main effects of pST injection (treatments 3 and 4 vs treatments 1 and 2) were observed for reduced ADFI (5.46 vs 7.53 lb, respectively; P<.001) and F/G (2.55 vs 3.91, respectively; P<.001); however, because of the reduced intake, no differences were observed in ADG (2.29 vs 2.23 lb, respectively). No interactive effects occurred between pST, salbutamol, and lysine for growth parameters. However, an interaction was seen between pST × lysine (P<.01) for plasma urea nitrogen, indicating that pST-treated pigs did not break down absorbed amino acids to urea at rates similar to pigs not injected with pST. Dietary lysine level caused linear (P<.04) and quadratic (P<.001) reductions in ADFI, translating into a quadratic (P<.04) reduction in ADG. Performance data indicated that pigs treated with pST have a lysine requirement between 1.2 and 1.6%. This was supported by plasma urea nitrogen, which demonstrated linear, quadratic, and cubic (P<.001) increases with increasing lysine level. Pigs treated with salbutamol appeared to have no higher requirement for dietary lysine on a percentage basis than pigs not treated, which may be confounded because salbutamol increased ADFI.

Digestibility of dry matter and nitrogen (Table 3) were higher for pST-treated pigs (89.88 vs 88.34 for dry matter; 90.80 vs 88.53 for nitrogen; main effect, P<.01), whereas pigs treated with salbutamol did not alter the digestibility of dry matter or nitrogen. There were no interactive effects of pST and salbutamol for digestibility data, indicating different modes of action for the two compounds. Lysine level tended (P<.15) to cause quadratic improvements in dry matter digestibility and quadratic (P<.02) and cubic (P<.05) improvements in dietary nitrogen digestibility, demonstrating that dietary amino acid excesses are digested and utilized less efficiently. This becomes clearer when using apparent biological value of dietary nitrogen (amino acids) as a measure of efficiency, where an interaction between pST and lysine (P<.05) is observed, indicating that pST-treated pigs benefit from increased lysine levels, resulting in improved biological value of nitrogen.

Retained nitrogen was interactively affected by pST and salbutamol when measured daily (P<.14) or as a percent of intake (P<.10), suggesting that salbutamol increases the efficiency of nitrogen utilization of pST-treated pigs. Significant interactions occurred between pST and lysine for daily nitrogen retention (P<.07) and percent nitrogen retention (P<.05), demonstrating that pigs injected with pST had improved nitrogen retention at higher lysine levels than non-injected pigs, with a maximum occurring between 1.2 and 1.6% lysine for daily nitrogen retention and between .8 and 1.2% lysine for percent nitrogen retention. Although no interaction was observed between pST, salbutamol, and lysine level, these data suggest that pigs treated with pST and salbutamol had a slightly lower lysine requirement than pigs treated with pST alone. This again may be interrelated to increased daily lysine intake with salbutamol.

Carcass data (Table 4) indicate that pST increased (P<.01) percent muscle, longissimus muscle area, and kidney and liver weight. Similarly, average backfat and tenth rib fat were decreased (P<.001) with pST administration, as well as kidney fat and dressing percent (P<.01). Salbutamol tended to reduce kidney and liver weight as a percent of live weight (P<.09 and P<.02, respectively), increase length (P<.05), and decrease carcass shrink (P<.001). Salbutamol and pST interactively (P<.01) influenced dressing percent, which was attributable to possible reductions in organ weights of salbutamol-treated pigs.

Conclusions

These data indicate that pigs injected daily with 4 mg pST have a lysine requirement between 1.2 and 1.6%. Furthermore, pigs fed salbutamol at 2.75 ppm of the diet do not appear to have a higher lysine requirement than non-treated pigs and appear to utilize an .8% level of lysine in the diet more efficiently. Subsequently, administration of pST and feeding salbutamol appear to be additive in terms of nitrogen retention and efficiency of utilization. Thus, pigs receiving both may respond adequately at a lower lysine level than pigs treated with pST alone, which may be related to increases in feed intake caused by salbutamol. These data are useful in determining the optimal range needed to observe maximal performance; however, they cannot recommend one value using such a wide range of lysine levels.

Table 1. Composition of Basal Diets (as fed)[a]

	Lysine level, %[b]			
Ingredient, %	.80	1.20	1.60	2.00
Corn	84.67	72.38	57.24	42.19
Soybean meal, 48%	-	12.50	28.00	43.35
Fish meal, select menhaden	5.00	5.00	5.00	5.00
Porcine plasma protein	5.00	5.00	5.00	5.00
Soybean oil	2.00	2.00	2.00	2.00
Monocalcium phosphate, 21% P, 18% Ca	1.96	1.75	1.48	1.21
Limestone	.66	.60	.54	.48
Salt	.25	.25	.25	.25
Vitamin premix	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15
L-lysine-HCl, 98%	.06	.11	.05	-
Dl-methionine, 99%	-	.01	.04	.10
L-threonine	-	-	-	.02
Total	100.00	100.00	100.00	100.00
Calculated analysis				
Metabolizable energy , kcal/lb	1,507	1,508	1,511	1,514
Crude protein, %	13.71	18.66	24.70	30.69
Crude protein, %[b]	14.53	18.94	25.00	30.75
Tryptophan, %	.15	.23	.33	.42
Threonine, %	.64	.83	1.07	1.33
Methionine, %	.27	.34	.46	.59
Ca, %	.90	.90	.90	.90
P, %	.80	.80	.80	.80

[a]Salbutamol was included at 2.75 ppm to each diet.
[b]Analyzed content.

Table 2. Interactive Effects of pST, Salbutamol, and Lysine Level on Growth Performance and Plasma Urea Nitrogen of Finishing Pigs[a]

pST, mg/d	Salbutamol, ppm	Lysine, %	ADG, lb[b]	ADFI, lb[c]	Feed/gain, lb/lb[d]	PUN, mg/dl[ef]
0	0	.8	2.34	7.61	3.54	13.43
0	0	1.2	2.05	7.60	3.98	19.24
0	0	1.6	1.97	7.26	4.94	23.55
0	0	2	1.60	6.28	5.64	28.70
0	2.75	.8	2.89	8.76	3.07	17.93
0	2.75	1.2	2.49	8.11	3.29	23.37
0	2.75	1.6	2.30	7.57	3.62	27.87
0	2.75	2	2.20	7.07	3.22	36.30
4	0	.8	1.90	5.56	3.08	6.11
4	0	1.2	2.16	5.66	2.66	7.92
4	0	1.6	2.17	5.39	2.66	12.25
4	0	2	1.93	4.51	2.90	14.59
4	2.75	.8	2.50	6.05	2.45	5.85
4	2.75	1.2	2.88	6.10	2.15	8.07
4	2.75	1.6	2.71	5.18	1.94	12.13
4	2.75	2	2.10	5.23	2.58	14.95
		SE	.33	.32	.81	1.26

[a]Values are means of four pigs (137 lb average initial wt) fed each diet for 8 d periods.
[b]Main effect of salbutamol (P<.01); quadratic (P<.11) effect of lysine level.
[c]Main effects of pST (P<.001) and salbutamol (P<.04); linear (P<.04) and quadratic (P<.001) effects of lysine level.
[d]Main effects of pST (P<.001) and salbutamol (P<.01).
[e]Plasma urea nitrogen.
[f]Interactive effects of pST × salbutamol (P<.14) and pST × lysine (P<.01); main effects of pST (P<.001) and salbutamol (P<.13); linear, quadratic, and cubic effect of lysine level (P<.001).

Table 3. Interactive Effects of pST, Salbutamol, and Lysine Level on Finishing Pig Nitrogen Metabolism[a]

pST,	Salbutamol,	Lysine,	Digestibility, %		Nitrogen retained		Apparent
mg/d	ppm	%	Dry matter[b]	Nitrogen[c]	g/d[d]	%[e]	BV, %[fg]
0	0	.8	88.63	87.52	38.17	47.22	54.03
0	0	1.2	88.75	88.81	48.76	44.08	49.61
0	0	1.6	87.68	88.56	44.16	33.63	37.97
0	0	2	87.66	88.02	60.25	40.17	45.67
0	2.75	.8	89.14	88.55	53.92	52.33	59.10
0	2.75	1.2	88.47	88.10	50.95	46.17	52.31
0	2.75	1.6	88.31	88.62	64.35	45.75	51.93
0	2.75	2	88.09	90.08	85.26	51.61	57.27
4	0	.8	89.49	88.92	39.22	60.32	67.95
4	0	1.2	90.25	91.03	55.17	63.78	70.11
4	0	1.6	90.22	91.47	68.37	60.00	65.60
4	0	2	90.38	91.82	59.19	52.59	57.31
4	2.75	.8	89.81	89.65	45.53	64.24	71.66
4	2.75	1.2	90.09	90.70	58.04	64.69	71.47
4	2.75	1.6	89.49	90.95	66.11	60.14	66.24
4	2.75	2	89.35	91.87	69.58	55.95	60.82
		SE	.58	.77	5.95	3.24	3.55

[a]Values are means of four pigs (137 lb average initial wt) fed each diet for 8 d periods.
[b]Effect of pST (P<.01); quadratic effect of lysine level (P<.15).
[c]Main effect of pST (P<.01); quadratic (P<.02) and cubic (P<.05) effects of lysine level.
[d]Interactive effects of pST × salbutamol (P<.14) and pST × lysine (P<.07); main effect of salbutamol (P<.02); quadratic (P<.001) and cubic (P<.02) effects of lysine level.
[e]Interactive effects of pST × salbutamol (P<.10) and pST × lysine (P<.05); main effects of pST (P<.001) and salbutamol (P<.01); quadratic (P<.01) effect of lysine level.
[f]Apparent biological value of nitrogen.
[g]Interactive effects of pST × salbutamol (P<.15) and pST × lysine (P<.05); main effects of pST (P<.001) and salbutamol (P<.02); quadratic (P<.001) effect of lysine level.

Table 4. Interactive Effects of pST and Salbutamol on Carcass Characteristics of Finishing Pigs[a]

Item	pST, mg/d Salbutamol, ppm	0 0	0 2.75	4 0	4 2.75	SE
Muscle, %[b]		49.88	50.73	56.11	55.94	.97
Loin muscle area, in^2 [c]		5.03	5.22	5.71	6.11	.25
Average backfat, in[b]		1.47	1.50	1.21	1.23	.04
Tenth rib fat, in[b]		1.34	1.29	.84	.85	.09
Length, in[d]		29.30	29.68	28.26	29.78	.44
Kidney, g[b]		346.14	309.48	458.31	434.86	22.14
Kidney, %[be]		.37	.33	.49	.46	.02
Kidney fat, g[c]		1284.85	1289.31	932.20	727.31	141.01
Kidney fat, %[c]		1.36	1.38	.95	.80	.13
Liver, g[b]		1556.61	1488.93	1991.97	1779.40	77.89
Liver, %[bf]		1.68	1.57	2.17	1.86	.07
Dressing percent, %[bfg]		75.35	75.06	72.39	74.63	.36
Carcass shrink, %[h]		2.42	1.91	2.73	1.94	.11

[a]Values are means of four pigs per treatment, except for pigs receiving both pST and salbutamol, which is represented by five pigs. Average initial wt was 137 lb.
[b]Main effect of pST (P<.001).
[c]Main effect of pST (P<.01).
[d]Main effect of salbutamol (P<.05).
[e]Main effect of salbutamol (P<.09).
[f]Main effect of salbutamol (P<.02).
[g]Salbutamol × pST interaction (P<.01).
[h]Main effect of salbutamol (P<.001).

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EFFECTS OF PORCINE SOMATOTROPIN AND DIETARY PHOSPHORUS ON GROWTH AND BONE CRITERIA IN GILTS

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Summary

One hundred-eight gilts with an average initial wt of 129 lb were utilized to determine the effects of porcine somatotropin (pST) and dietary phosphorus on growth performance and bone mineralization and mechanical properties during the finishing phase (129 to 230 lb) and a 35 d post-finishing phase. Gilts were injected daily with placebo (control) or 4 mg pST and fed diets containing .4, .8, or 1.2% P during the finishing phase. Administration of pST improved F/G 18%, increased ADG 8%, and decreased daily feed intake 9%. There was a quadratic response to P, because gilts receiving the .8% P diet were more efficient than gilts fed either .4 or 1.2% P, regardless of whether they received pST or placebo. When pen wt reached 230 lb, half of the gilts were slaughtered and 1st rib, femur, and 3rd and 4th metacarpals were collected. First rib ash content increased linearly as the level of dietary P increased; however, pST administration had no effect on ash content. There was a pST × P interaction for rib bending moment, stress, and modulus of elasticity. Bone strength was maximized for control gilts at .8% P, whereas bone strength continued to increase as the level of dietary P was increased for pST-treated gilts. The remaining 54 gilts were individually fed 4 lb/d of a common diet for a 35 d post-finishing phase and then slaughtered. Gilts that received higher P levels in the finishing phase had higher rib ash content at the end of the post-finishing phase. There was a pST × P interaction for treatment combination received in the finishing phase on rib and femur bending moment post-finishing. Bone strength for pST-treated gilts receiving the .8 or 1.2% P diet in the finishing phased increased to levels exceeding those of control gilts by the end of the post-finishing phase, regardless of dietary P level control gilts were fed in the finishing phase. These data indicate that gilts administered pST in the finishing phase do not have higher Ca and P requirements than non-pST treated gilts to maximize growth performance. However, pST-treated gilts do have higher requirements for Ca and P than non-pST treated gilts to attain comparable bone strength in the finishing phase. Gilts receiving pST in the finishing phase demonstrate compensatory mineralization in the post-finishing phase, because bone strength increases to equal or exceed that of control gilts fed similar P levels.

(Key Words: Repartition, Performance, Gilts, Phosphorus, Bone.)

Introduction

Porcine somatotropin (pST) alters metabolism of carbohydrates, proteins, and lipids to significantly improve growth performance and carcass characteristics. These improvements have been well documented; however, the effect of pST on mineral metabolism and bone development is less defined. Because pST increases the lysine requirement for finishing pigs, Ca and P requirements also may be increased. Recent research has indicated some mobility problems in gilts administered pST. A possible reason for these may be that bones of pST-treated pigs are weaker than those of non-pST-treated pigs, as observed during slaughter at the end of the finishing period. This would seem to indicate that

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pST-treated gilts would have reduced durability and longevity in the sow herd. Conversely, pST-treated pigs have been shown to have increased growth of the collagen matrix, indicating that their bone is less mature and may have the potential for compensatory mineralization. Therefore, this study was conducted to evaluate the effects of pST administration and dietary P on growth performance and bone mineralization and mechanical properties in finishing gilts and to determine if compensatory bone mineralization would occur in pST-treated gilts during a 35 d post-finishing period.

Procedures

A total of 108 crossbred gilts (initial wt = 129 lb) were allotted on the basis of weight and ancestry in a 2 × 3 factorial arrangement to one of six experimental treatments. Experimental treatments consisted of daily injections of placebo or 4 mg pST in combination with a corn-soybean meal diet (Table 1) containing either .4, .8, or 1.2% phosphorus. This corresponds to 100, 200, and 300% of the NRC (1988) recommendations for P in finishing diets. Dietary P levels were attained by replacing corn with monocalcium P and limestone. All finishing diets were formulated to contain 1.2% lysine, and a constant Ca:P ratio of 1.25:1 was maintained throughout the experiment. All nutrients except Ca and P were formulated to be at least 200% of NRC (1988) recommendations for finishing pigs. There were three gilts per pen and six replicates per treatment. Gilts were housed in an open-front building with solid concrete floors in 4 × 15 ft pens. Feed and water were supplied ad libitum, and straw was used for bedding as needed. All gilts and feeders were weighed on d 14 and 28, then weekly thereafter until mean pen weight reached 230 lb. Gilts were injected daily in the extensor muscle of the neck until the pen mean weight reached 230 lb, at which time injections were terminated and 54 gilts were slaughtered (nine per treatment). The femur, 1st rib, and 3rd and 4th metacarpals were removed from the right side of the carcass, labeled, and frozen for later analyses.

In the 35 d post-finishing phase, the remaining 54 gilts (nine per treatment) were individually fed 4 lb/d of a common diet (Table 1) to ensure daily intakes of 22.9 g P. This corresponds to 200% of the NRC (1988) recommended daily P intake for developing gilts. An additional 1 lb of corn for extra energy was offered to all gilts after consumption of the 4 lb was complete. At the end of the 35 d period, all gilts were slaughtered and bones were collected as described for the finishing phase.

Bones were manually cleaned of connective tissues and were constantly stored in plastic bags prior to mechanical determination on an Instron Universal Testing Machine (Instron Corp., Canton, MA) to prevent drying, with the exception of the few minutes when bones were cleaned. After testing, bones were cleaned of any remaining residue, extracted in petroleum ether for 48 h, and dried prior to ashing. All bones were ashed at 1,112°F for 12 h. Ash is the mineral content of the bone, expressed as a percentage of the dried, fat-free bone.

Mechanical properties of bones must be assessed through equations derived to evaluate the strength and elasticity of bones that differ in size and shape. These equations are similar to those used to evaluate strength and durability of building materials. Bending moment refers to the actual force required to "break" or more appropriately bend a bone, adjusted for differences in the span over which the force is applied. Stress adjusts the force for the area and shape of the bone at the point where the force is applied. Stress actually gives a better estimate of the bones overall strength than bending moment. Modulus of elasticity gives a measure of the ability of the bone to return to its original shape, which is an indicator of the stiffness or rigidity of the bone. High values for modulus of elasticity indicate a high degree of rigidity, whereas lower values indicate a more flexible bone. Strain is a measure of the amount of deformation that takes place in the bone while it is being tested.

Results and Discussion

Growth performance data are reported as interaction means in Table 2. However, main effects of pST and dietary P will be discussed, because no pST × P interactions (P>.25) occurred for growth performance. In a typical pST response, gilts administered pST had higher (P<.01) average daily gain (ADG), were more efficient (P<.01), and consumed approximately .6 lb/d less feed than placebotreated gilts over the entire finishing period. From d 0 to 35 of the finishing phase, gilts receiving the .4% P diet had reduced (linear, P<.05) ADG compared to gilts fed the .8 and 1.2% P diets, regardless of whether they received pST or not. This can be explained by daily feed intakes below NRC (1988) estimates on all diets and subsequently reduced daily P intakes during this period for the gilts fed .4% P diet, which were 2 to 3 g below the NRC (1988) daily recommendation of 1.3 g. However, for the overall finishing phase (129 to 230 lb), ADG was unaffected by dietary P level. There was a P effect (quadratic, P<.06) on F/G, because gilts were most efficient when fed .8% dietary P from d 0 to 35 and for the entire finishing phase, whether pST was administered or not. This should not be interpreted as .8% P being the optimal dietary level to feed in order to maximize F/G, because the dietary levels (.4 to 1.2% P) cover a wide range. Consequently, daily P intakes ranged from slightly deficient on the .4% P diet, because of feed intakes below NRC (1988) estimates, to far in excess of current NRC (1988) recommended daily intakes of P in the 1.2% P diet.

For the finishing phase, a pST × dietary P interaction (P<.05) occurred for rib bending moment; placebo-treated gilts had highest rib strength at .8% P and then a slight decline at 1.2% P. In contrast, pST-treated gilts showed increased rib strength as the level of dietary P increased, although values for the 1.2% P diet were still below those the control gilts attained on the .8% P diet (Table 3). Rib stress followed a similar trend (pST × P interaction, P<.12), with highest strength attained by the control gilts on the .8% P diet and increasing rib strength for the pST-treated gilts as dietary P was increased. Rib strain was unaffected (P>.19) by either pST administration or dietary P level. Modulus of elasticity for the rib showed a pST × P interaction (P<.05), with control gilts having more rigid bones at all P levels, whereas pST-treated gilts had the highest degree of flexibility at the .4% P level. This would agree with previous research that showed increased collagen formation but decreased calcification of the bone protein matrix in pST-treated pigs. The femur bending moment increased (linear, P<.04) as the level of dietary P was increased. Although the pST × P interaction was not significant for femur bending moment, a similar trend occurred as in the rib with bending moment being highest for control gilts at .8% P and pST gilts at 1.2% P. However, femurs from pST-treated gilts fed 1.2% P diets had higher bending moments than those of any of the control gilts. Bending moment for the metacarpal increased (linear, P<.01 and quadratic, P<.06) as dietary P increased. Gilts administered pST had decreased (P<.04) bending moments compared to control gilts. The metacarpal bones were less responsive than rib or femur to dietary P levels. This would be expected, because the metacarpal bones were the furtherest skeletal extremities to be evaluated, and the skeletal extremities are less sensitive to demineralization. However, a similar trend in metacarpal bending moment was noted, with control gilts having the highest bending moment on .8% P and pST-treated gilts on 1.2% P.

Rib ash content increased (linear, P<.01 and quadratic, P<.06) as dietary P increased, whether gilts received pST or not (Table 3). In previous research, pST-treated pigs had decreased ash content as lysine level was increased. However, in this experiment, lysine levels were constant at 1.2%, and, consequently, daily lysine, Ca, and P intakes between control and pST-treated pigs were similar. Ash contents were lower across all treatments than typically measured for pigs fed lower lysine diets, because increasing protein levels results in increased collagen matrix formation and slight decreases in bone ash content. This agrees with previous research showing decreased ash content as protein level was increased.

In the post-finishing phase, pST × P interactions (P<.03) were observed for rib bending moment and strain (Table 4). At the end of the post-finishing phase, bending moment for rib and femur of pST-treated gilts on the .8% P diet was as high as bending moment for any of the control gilts. Additionally, pST-treated gilts fed 1.2% P in the finishing phase had bending moments at the end of the post-finishing phase that exceeded those of all control gilts. These results indicate that compensatory mineralization occurs in the post-finishing phase. Post-finishing rib stress was unaffected by treatment received in the finishing phase. However, a similar pattern of highest rib strength per unit area was found in control gilts fed .8% P in the finishing phase, whereas rib strength increased in pST-treated gilts as the dietary P level was increased. Post-finishing rib modulus of elasticity had no carryover effects from treatment received in the finishing phase, although pST-treated gilts tended to have less rigid bones. Metacarpal bending moments were unaffected by previous treatments received in the finishing phase, although bending moments increased substantially from the finishing phase. Rib ash was increased (linear, P<.01 and quadratic, P<.10) by increased P levels received in the finishing phase. Administration of pST had no effect on post-finishing ash content.

Our data indicate that commonly fed finisher diets containing .45 to .55% P should be adequate to maintain maximum growth performance in pST-treated gilts. Mobility was not a problem in this experiment, because no differences in mobility or structural soundness through live evaluation were found to be due to pST treatment or dietary P level.

Bone strength was maximized in the non-pST-treated gilts at .8% P, whereas dietary P levels at 300% of NRC(1988) recommendations did not maximize bone strength in pST-treated gilts during the finishing phase. This suggests that maximum bone strength of pST-treated gilts may not be attainable without using excessively high levels of P that may depress intake and, consequently, growth performance. In contrast, compensatory increases in bone strength of pST-treated gilts post-finishing potentially offers an alternative to increasing bone strength by feeding extremely high P levels in the finishing phase. Further research needs to be conducted to determine the P intake required to facilitate post-finishing compensatory mineralization and to determine the time needed for the compensatory effect. Extrapolation of our results suggests that with compensatory mineralization, longevity of pST-treated gilts in the breeding herd should not be decreased by reduced bone strength and mineralization.

In conclusion, pST-treated finishing gilts do not have higher requirements for Ca and P than non-pST treated gilts for maximizing gain and feed efficiency. Gilts treated with pST do have higher requirements for Ca and P to achieve similar levels of bone strength in the finishing phase. However, through compensatory mineralization post-finishing, gilts treated with pST appear to have the capability of increasing bone strength to levels equal to or above those of non-pST-treated gilts.

Table 1. Composition of Diets

	Finishing phase[a]			Post-finishing[b]
Ingredient, %	.4 P	.8 P	1.2 P	1.2 P
Corn	62.98	60.65	58.32	78.69
Soybean meal (48% CP)	29.77	29.77	29.77	14.53
Soybean oil	5.00	5.00	5.00	—
L-lysine HCl	.16	.16	.16	—
Monocalcium P (21% P)	.16	2.10	4.03	4.22
Limestone	.78	1.17	1.57	1.66
Salt	.30	.30	.30	.50
Vitamin premix	.50	.50	.50	.25
Trace mineral premix	.20	.20	.20	.10
Selenium premix	.05	.05	.05	.05
Antibiotic[c]	.10	.10	.10	--
Total	100.00	100.00	100.00	100.00
Calculated analyses, %				
Lysine	1.2	1.2	1.2	.65
Ca	.5	1.0	1.5	1.5

[a]Finishing phase, 129 to 230 lb.
[b]Post-finishing, 35 d following the finishing phase.
[c]Each lb of antibiotic contained 10 g chlortetracycline.

Table 2. Effect of Porcine Somatotropin and Dietary Phosphorus on Growth Performance of Finishing Gilts[a]

	Placebo			4 mg pST			
Item	.4 P	.8 P	1.2 P	.4 P	.8 P	1.2 P	CV
0 to 35 d[b]							
ADG, lb[ceh]	1.79	2.01	1.94		2.07	2.06	7.9
Feed intake, lb/d[d]	5.37	5.53	5.59		4.90	4.97	9.0
F/G[de]	3.04	2.81	2.91		2.40	2.45	6.9
P intake, grams/d[df]	9.7	20.1	30.4	8.7	17.8	27.1	10.8
Finishing phase[g]							
ADG, lb[d]	1.78	1.99	1.87		2.05	2.07	8.4
Feed intake, lb/d[d]	5.64	6.09	6.14		5.26	5.48	5.9
F/G[de]	3.20	3.13	3.35		2.58	2.67	5.7
P intake, grams/d[df]	10.2	22.1	33.4	9.7	19.1	29.8	7.2

[a]A total of 108 gilts initially weighing 129 lb, 3 gilts/pen, 6 pens/treatment.
[b]Day 0 to 35 of the finishing phase.
[c]Effect of pST (P<.08).
[d]Effect of pST (P<.01).
[e]Effect of phosphorus (quadratic (P<.06).
[f]pST × phosphorus interaction (P<.04).
[g]The entire finishing phase, d 0 until pen wt averaged 230 lb.
[h]Effect of phosphorus (linear, P<.05).

Table 3. Effect of Porcine Somatotropin and Dietary Phosphorus on Bone Mechanical Properties and Mineralization (Finishing Phase)[a]

	Placebo			4 mg pST			
Item	.4 P	.8 P	1.2 P	.4 P	.8 P	1.2 P	CV
Rib							
Bending moment, kg[b]	86	125	119	54	104	120	19.4
Stress, kg/cm^2[cef]	602	624	609	298	576	609	40.5
Strain	.22	.29	.23	.24	.25	.26	29.6
Modulus of elasticity kg/cm^2[b]	2,974	3,022	2,816	1,260	2,174	2,828	55.6
Ash, %[de]	44.99	48.79	50.51	43.68	49.64	51.39	5.7
Femur							
Bending moment, kg[e]	484	603	598	394	569	664	22.5
Metacarpal							
Bending moment, kg[cde]	144	174	169	121	161	168	13.3

[a]Means represent 9 observations per treatment.
[b]pST × P interaction ($P<.05$).
[c]Effect of pST ($P<.06$).
[d]Effect of P (quadratic $P<.06$).
[e]Effect of P (linear $P<.04$).
[f]pST × P interaction ($P<.10$).

Table 4. Effect of Porcine Somatotropin and Dietary Phosphorus during the Finishing Phase on Bone Mechanical Properties and Mineralization during a 35-d Post-finishing Phase[a]

	Placebo			4 mg pST			
Item	.4 P	.8 P	1.2 P	.4 P	.8 P	1.2 P	CV
Rib							
Bending moment, kg[b]	119	109	131	104	131	144	16.7
Stress, kg/cm^2	571	774	613	534	560	647	37.3
Strain[b]	.28	.20	.25	.26	.32	.31	29.5
Modulus of elasticity kg/cm^2	2,402	3,243	2,500	2,493	2,233	2,345	68.7
Ash, %[cd]	44.52	49.46	48.09	44.59	47.80	48.78	8.9
Femur							
Bending moment, kg[def]	517	611	561	566	643	739	17.3
Metacarpal							
Bending moment, kg	217	226	230	216	218	224	14.1

[a]Means represent 9 observations per treatment.
[b]pST × P interaction (P<.03).
[c]Effect of P (quadratic, P<.10).
[d]Effect of P (linear, P<.01).
[e]Effect of pST (P<.01).
[f]pST × P interaction (P<.12).

EFFECTS OF PORCINE SOMATOTROPIN ADMINISTRATION AND ITS DURATION ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF FINISHING SWINE FED TO 280 LB

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Summary

One hundred eight barrows with an initial weight of 120 lb were utilized to determine the effects of porcine somatotropin (pST) administration period and duration on growth performance and carcass characteristics of finishing swine fed to 280 lb. Pigs were injected daily in the extensor muscle of the neck with either a placebo or 4 mg pST. Treatments included: (A) placebo injection from 120 to 280 lb; (B) pST injection from 120 to 280 lb; (C) pST injection from 120 to 230 lb and then placebo injection from 230 to 280 lb; (D) placebo injection from 120 to 230 lb and then pST injection from 230 to 280 lb; (E) placebo injection from 120 to 170 lb, pST injection from 170 to 230 lb, and then placebo injection from 230 to 280 lb; and (F) placebo injection from 120 to 250 lb and then pST injection from 250 to 280 lb. All pigs were fed a corn-soybean meal diet containing 1.2% lysine. Performance data were collected and evaluated for three weight ranges:120 to 230 lb, 230 to 280 lb, and 120 to 280 lb. Two pigs from each pen were slaughtered to determine carcass characteristics. The first pig was slaughtered at 230 lb and the second pig at 280 lb. Average daily gain (ADG), average daily feed intake (ADFI), and feed conversion (F/G) were all optimized when pigs were treated with pST for the entire time from 120 to 230 lb and from 120 to 280 lb. Longissimus muscle area (LEA), backfat thickness, percentage carcass muscle, and kidney fat were all improved at 230 lb when pigs were injected with pST. There was no difference in these carcass traits when pigs were injected with pST from 120 to 230 lb compared to pigs treated with pST from 170 to 230 lb. These same carcass characteristics measured in pigs slaughtered at 280 lb showed significant improvement with pST treatment compared to the control. However, when pST treatment lasted the entire trial (120 to 280 lb), there was significant improvement in carcass characteristics over pST treatments of shorter duration. Whole ham weight was unaffected by pST treatment at either slaughter weight, but trimmed ham weight was improved by pST treatment at 230 lb. Daily protein accretion rate (DPA) and daily fat accretion rate (DFA) were optimized at both slaughter weights by pST treatment that lasted for the duration of the trial. Organ weights were increased by pST treatment but were unaffected by administration period or duration of pST treatment. These data indicate that growth performance and carcass characteristics were maximized when pST was administered continually from 120 to 280 lb.

(Key Words: Repartition, GF, Performance, Carcass, Heavy Weight.)

Introduction

To take advantage of inexpensive grain prices and maximize packing plant efficiency, many swine producers are marketing their hogs at much heavier weights. A drawback to this trend is the characteristic slow growth and excessive fat deposition of these pigs after they reach 230 lb. The decline in growth rate can be costly to the producer by slowing down production flow and tieing up facilities. Also, overly fat pork does not have high consumer or packer appeal.

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Use of pST during the finishing phase has the potential to alter pig performance and make it more advantageous to feed pigs to heavier weights. Because of the costs in time and labor of injecting pST, it is necessary to determine the proper time of administration and duration of treatment to achieve maximum benefit.

Therefore, the objective of this experiment was to determine the effects of pST administration and its duration on growth performance and carcass characteristics of finishing pigs fed to 280 lb.

Procedures

One hundred eight crossbred barrows (Yorkshire × Duroc × Yorkshire) with an average initial weight of 120 lb were allotted on the basis of weight and ancestry to one of six treatments. Pigs were housed in a modified open front building with three pigs per pen and six pens per treatment. Treatments included: (A) placebo injection from 120 to 280 lb; (B) pST injection from 120 to 280 lb; (C) pST injection from 120 to 230 lb and then placebo injection from 230 to 280 lb; (D) placebo injection from 120 to 230 lb and then pST injection from 230 to 280 lb; (E) placebo injection from 120 to 170 lb, pST injection from 170 to 230 lb, and then placebo injection from 230 to 280 lb; and (F) placebo injection from 120 to 250 lb and then pST injection from 250 to 280 lb. Injections were given daily in the extensor muscle of the neck and pST dosage level was 4 mg. Pigs were fed a corn-soybean meal diet (Table 1) containing 1.2% dietary lysine. The diet was formulated to contain at least 200% of NRC (1988) recommendations for other amino acids. Pigs were weighed at 14-d intervals until the mean weight of pigs in a pen reached 230 lb. At this time, one pig per pen was slaughtered for recording carcass measurements and organ weights. The other two pigs remained on experimental treatment and were weighed at 7-d intervals until they reached a final mean weight of 280 lb. One of the two remaining pigs was then slaughtered for carcass measurements and organ weights. At the start of the trial, six pigs with an average weight of 120 lb were slaughtered, and the right hams were ground to determine a baseline for protein and fat composition. Pigs slaughtered at 230 and 280 lb had the right ham removed and ground for determination of protein and fat accretion rates. A whole ham weight was recorded. The fat then was removed, and the ham was reweighed to obtain a trimmed ham weight. Each ham was also evaluated for color, firmness, and marbling. Production measurements taken included ADG, ADFI, and F/G.

Table 1. Composition of Diet

Ingredients	Percentage
Corn	54.55
Soybean meal (48%)	34.10
D-L methionine	.05
Soybean oil	6.00
Monocalcium phosphate	3.05
Limestone	1.00
Vitamin premix	.50
Trace mineral premix	.20
Selenium premix	.05
Salt	.50
Total	100.00
Calculated analysis, %	
Crude protein	20.84

Results and Discussion

Average daily gain for pigs fed from 120 to 230 lb (Table 2) was greatest for those pigs that received pST during this entire time. Pigs treated with pST from 120 to 230 lb gained 20% faster than the pigs that received no pST (P<.01) and 12% more than the pigs that were treated with pST from 170 to 230 lb. There was a decrease (P<.05) in ADFI for pST-treated pigs, with control pigs consuming 7% more feed. There was no difference in ADFI when comparing pigs treated with pST for the entire time to pigs treated for the shorter period. Feed conversion was improved (P<.01) for pST-treated pigs by 24% compared to the control pigs receiving placebo injections. Pigs that were pST-treated from 120 to 230 lb had an average improvement of 15% in F/G (P<.01) over pigs that received pST from only 170 to 230 lb.

In terms of performance from 230 to 280 lb, ADG was 25% higher (P<.01) for those pigs receiving pST compared to control pigs. Pigs that received pST from 250 to 280 lb showed a 33% increase in ADG when compared to pigs that were pST-treated from 230 to 280 lb. Daily feed intake was greater (P<.01) for placebo-injected and pigs injected with pST from 250 to 280 lb compared to pigs receiving pST for the entire time period. Porcine somatotropin-treated pigs consumed 28% less feed than the other pigs during this period of the trial. Feed conversion was improved (P<.01) for pST-treated pigs by 37% compared to control pigs. There was no difference in F/G between pST treatments.

There was a numerical advantage in daily gain for pigs treated with pST for the entire trial (120 to 280). These pigs had a 10% increase in gain over pigs that received no pST or pST treatment for a shorter duration of the trial. Control pigs receiving placebo injections for the entire trial consumed 15% more feed (P<.01) than pigs receiving pST treatment for the entire trial. There was no difference (P>.17) in ADFI between pST treatments, but pigs treated with pST for the entire trial did have a numerical reduction in feed consumption of 8% compared to pigs treated with pST for shorter durations. Feed conversion was optimized (P<.01) for pigs treated with pST for the entire trial, with those pigs showing a 20% improvement in F/G over pigs that received no pST and a 15% improvement over pigs treated with pST for a shorter duration.

When pigs were slaughtered at 230 lb, there was a reduction (P<.01) in average backfat thickness. Pigs injected with pST had 20% less backfat than control pigs (Table 3). Duration of pST treatment had no significant effect on LEA, but there was an 8% increase in LEA when pigs were given pST for the entire time rather than receiving it from 170 to 230 lb. All pST-treated pigs showed a 23% increase in LEA (P<.01) when compared to placebo-treated pigs. Percentage carcass muscle increased 12% (P<.01) for pST-treated pigs slaughtered at 230 lb compared to control pigs killed at the same weight. Kidney fat was 35% less (P<.01) when pigs were injected with pST compared to no pST treatment. Whole ham weight was not affected by pST, but trimmed ham weight increased 6% (P<.05) with pST treatment. The subjective evaluation of ham color showed no effect from pST or duration of treatment. Ham firmness was affected by pST treatment, with all pST-treated pigs having a 17% decrease (P<.04) in firmness compared to control pigs. Porcine somatotropin treated pigs also had a significant decrease in marbling (P<.03). Hams from pST-treated pigs slaughtered at 230 lb scored 34% lower in marbling than hams from control pigs.

Pigs slaughtered at 280 lb exhibited 11% less backfat (P<.04) when treated with pST for the entire trial (120 to 280 lb) than when given pST for a shorter duration or not at all. There was a 13% increase (P<.03) in LEA when pigs were given pST injections for the entire time of the trial. Percentage carcass muscle was also increased (P<.01) with increasing duration of pST treatment. Those pigs injected with pST showed a 6% increase in percentage carcass muscle compared to pigs only receiving a placebo injection. Pigs injected with pST for the entire trial had an 8% increase (P<.01) in percent muscle compared to pigs treated with pST for a shorter duration. Kidney fat was decreased by 28% (P<.01) when pigs were injected with pST compared to control pigs. Pigs treated with pST for the entire trial and from 230 to 280 lb showed an average decrease of 29% in kidney fat compared to the other pST-treated pigs. Whole ham weight and trimmed ham weight of pigs slaughtered at 280 lb was unaffected by pST treatment of any duration when compared to control pigs. Ham color and firmness scores were also unaffected when pigs were treated with pST. Ham marbling showed a significant decrease (P<.04) of 25% when pigs were treated with pST. Pigs treated with pST for the entire duration of the trial showed a numerical trend (P<.06) toward less marbling when compared to pST treatments of shorter duration.

Daily protein accretion rate was increased (P<.01) by 55% when pigs were treated with pST and slaughtered at 230 lb (Table 4). Among pST treatments, those pigs receiving pST from 120 to 230 lb had a 35% increase (P<.01) in DPA compared to pigs injected with pST from 170 to 230 lb. Daily fat accretion (DFA) rate was 69% lower for pST-treated pigs (P<.01), with pigs receiving pST for the entire time having a 66% lower DFA (P<.02) than pigs injected with pST from 170 to 230 lb. Pigs slaughtered at 280 lb showed an increase (P<.01) in DPA when given pST for the entire trial. Pigs treated with pST from 120 to 280 lb had a 34% increase in DPA compared to control pigs and a 28% increase in DPA compared to pST-treated pigs on the other treatments. Fat accretion rate was 28% lower (P<.05) when averaged across all pST treatments than it was for pigs receiving a placebo injection. Pigs receiving pST from 120 to 280 lb, from 120 to 230 lb, and from 230 to 280 lb had a 43% reduction in DFA compared to pigs injected with pST from 170 to 230 lb and from 250 to 280 lb.

Organ weights recorded at the time of slaughter included heart, liver, kidneys, lungs, and spleen (Table 5). All organ weights for pigs slaughtered at 230 lb were significantly heavier (P<.03) for pigs treated with pST compared to control pigs. Pigs slaughtered at 280 lb had a significant increase (P<.05) in heart, liver, and kidney weights when treated with pST. Those pigs treated with pST for the entire trial showed an increase (P<.03) in organ weight when compared to the pigs on pST treatments that were shorter in duration.

The results of this study indicate that growth performance of pigs fed to 230 or 280 lb is optimized when pigs are injected with pST for the entire finishing phase rather than for shorter durations. Porcine somatotropin treatment improved carcass traits of pigs slaughtered at 230 lb. However, there was no difference in carcass characteristics between pigs treated with pST from 120 to 230 lb and pigs that were pST-treated from 170 to 230 lb. Pigs slaughtered at the heavier weight of 280 lb had larger LEA, less backfat thickness, greater percent muscle, and less kidney fat when they were treated with pST from 120 to 280 lb compared to the pST treatments of shorter duration. Daily protein and fat accretion rates were improved (P<.05) at both slaughter weights for pigs given pST for the entire finishing phase. These results demonstrate that if pigs are fed to the conventional weight of 230 lb, carcass traits can be improved with pST injections from 170 to 230 lb. However, if pigs are to be fed to the heavier market weight of 280 lb, pigs must receive pST treatment for the entire time period (120 to 280 lb) to achieve optimum improvements in efficiency, carcass traits, and protein and fat accretion rates.

Table 2. Effect of pST Administration Period and Duration on Growth Performance[a]

	Weight, lb	PST (+) or Placebo (–) Injection					
	120-170	–	+	+	–	–	–
	170-230	–	+	+	–	+	–
	230-250	–	+	–	+	–	–
Item	250-280	–	+	–	+	–	+
ADG, lb							
120-230		1.87[bc]	2.19[d]	2.24[d]	1.93[c]	1.98[c]	1.72[b]
230-280		1.97[cd]	1.64[bc]	1.44[b]	1.90[c]	1.32[b]	2.36[d]
120-280		1.89	2.05	2.02	1.87	1.83	1.84
ADFI, lb							
120-230		6.12	5.79	5.57	6.29	5.88	6.07
230-280		7.36[c]	5.34[b]	8.12[c]	5.38[b]	7.20[c]	7.08[c]
120-280		6.48[cdef]	5.62[b]	6.12[bd]	6.02[bc]	6.15[be]	6.16[bf]
F/G							
120-230		3.27[d]	2.65[b]	2.49[b]	3.26[d]	2.97[c]	3.54[e]
230-280		3.74[b]	3.66[b]	5.70[c]	2.87[b]	5.61[c]	3.02[b]
120-280		3.44[e]	2.75[b]	3.04[c]	3.22[cd]	3.37[de]	3.34[de]

[a]Each treatment mean represents six replications. There were three pigs per replication from 120 to 230 lb and two pigs per replication from 230 to 280 lb.
[bcdef]Means with unlike superscripts differ ($P<.05$).

Table 3. Effect of pST Administration Period and Duration on Carcass Characteristics[a]

	Weight, lb	pST (+) or Placebo (–) Injection					
	120-170	–	+	+	–	–	–
	170-230	–	+	+	–	+	–
	230-250	–	+	–	+	–	–
Characteristic	250-280	–	+	–	+	–	+
Backfat, in							
230 lb		1.40[c]	1.17[b]	1.04[b]	1.39[c]	1.15[b]	1.41[c]
280 lb		1.50[bc]	1.36[b]	1.47[b]	1.45[b]	1.52[bc]	1.73[c]
Longissimus, muscle, in^2							
230 lb		4.36[bd]	5.32[e]	5.45[e]	4.28[bc]	4.97[cde]	4.21[b]
280 lb		5.11[b]	5.97[d]	5.25[bc]	5.89[cd]	5.19[b]	5.05[b]
Percent muscle							
230 lb		50[b]	55[c]	58[d]	51[b]	55[c]	49[b]
280 lb		48[b]	54[e]	50[cd]	52[de]	50[bc]	48[b]
Kidney fat, g							
230 lb		1365[c]	848[b]	772[b]	1322[c]	899[b]	1194[c]
280 lb		2518[e]	1459[b]	1882[c]	1473[b]	1967[cd]	2315[de]
Whole ham weight, lb							
230 lb		19.97	20.45	20.73	20.33	20.35	20.22
280 lb		25.68	25.82	25.67	25.68	25.52	25.05
Trimmed ham weight, lb							
230 lb		15.82[b]	16.90[cde]	17.22[de]	15.88[b]	16.50[bd]	15.95[bc]
280 lb		19.88[bc]	20.65[c]	20.27[bc]	20.62[c]	19.57[bc]	19.17[b]
Ham color score[f]							
230 lb		2.92[bc]	2.42[b]	2.75[bc]	2.67[bc]	2.67[bc]	3.00[c]
280 lb		3.00[bc]	2.92[bc]	3.00[bc]	3.25[c]	2.83[bc]	2.67[b]
Ham firmness score[g]							
230 lb		2.83[b]	2.33[bc]	2.17[c]	2.50[bc]	2.17[c]	2.67[bc]
280 lb		2.80	2.67	2.50	2.58	2.83	2.67
Ham marbling score[h]							
230 lb		2.08[cd]	1.33[b]	1.33[b]	2.00[cd]	1.67[bc]	2.50[d]
280 lb		2.60[d]	1.50[b]	1.67[bc]	2.25[cd]	2.00[bcd]	2.33[cd]

[a]Each treatment mean represents six replications with one pig per replication.
[bcde]Means with unlike superscripts differ (P<.05).
[f]Based on a scale with 1=extremely pale, 3=uniformly grayish pink, 5=dark.
[g]Based on a scale with 1=soft and watery, 3=moderatley firm and dry, 5=very firm and dry.
[h]Based on a scale with 1=trace, 3=small, 5=abundant.

Table 4. Effect of pST Administration and Duration on Ham Protein and Fat Accretion Rates[a]

	Weight, lb	PST (+) or Placebo (–) Injection					
	120-170	–	+	+	–	–	–
	170-230	–	+	+	–	+	–
	230-250	–	+	–	+	–	–
Item	250-280	–	+	–	+	–	+
DPA, g							
120-230 lb		9.94[bc]	15.64[e]	16.90[e]	10.23[bd]	12.04[cd]	8.63[b]
120-280 lb		11.56[bc]	15.48[d]	14.43[cd]	13.94[cd]	10.62[b]	9.43[b]
DFA, g							
120-230 lb		15.41[d]	4.51[bc]	1.80[b]	16.91[d]	9.36[c]	17.64[d]
120-280 lb		21.84[d]	9.93[b]	14.06[bc]	11.91[b]	22.85[d]	19.30[cd]

[a]Each treatment mean represents six replications with one pig per replication.
[bcde]Means with unlike superscripts differ (P<.05).

Table 5. Effect of pST Administration Period and Duration on Organ Weight[a]

	Weight, lb	pST (+) or Placebo (–) Injection					
	120-170	–	+	+	–	–	–
	170-230	–	+	+	–	–	–
	230-250	–	+	–	+	–	–
Organ	250-280	–	+	–	+	–	+
Heart, g							
230 lb		326	356	377	328	372	333
280 lb		360[b]	421[cd]	405[cd]	392[bd]	355[b]	388[bc]
Liver, g							
230 lb		1542[b]	2124[c]	2110[c]	1751[b]	2059[c]	1592[b]
280 lb		1898[b]	2323[c]	1981[b]	2084[b]	1944[b]	2037[b]
Kidneys, g							
230 lb		375[b]	480[c]	453[c]	361[b]	454[c]	340[b]
280 lb		416[b]	525[c]	464[b]	448[b]	455[b]	453[b]
Lungs, g							
230 lb		752[b]	902[bc]	958[bd]	806[b]	1096[cd]	722[b]
280 lb		847	961	743	1043	867	1059
Spleen, g							
230 lb		148[bc]	187[de]	181[ce]	133[b]	178[cd]	139[b]
280 lb		172	213	203	226	186	188

[a]Each treatment mean represents six replications with one pig per replication.
[bcde]Means with unlike superscripts differ (P<.05).

CAUSES OF DIARRHEA, PNEUMONIA, AND SEPTICEMIA IN SWINE FOR 1991 SUBMISSIONS TO THE KSU VETERINARY DIAGNOSTIC LABORATORY

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Summary

Causes of pre- and postweaning diarrhea, pneumonia, and bacterial septicemia in pigs were summarized for fiscal year 1991 (July, 1990 to June, 1991) for submissions to the Kansas State University Veterinary Diagnostic Laboratory. *Escherichia coli* was the most common cause of both pre- and postweaning diarrhea in pigs (33.5% and 25.0%, respectively, of submissions for diarrhea). Other commonly diagnosed causes included transmissible gastroenteritis (24.4%) and coccidiosis (16.5%) for preweaning diarrhea, and proliferative enteritis (19.2%) and salmonellosis (13.2%) for postweaning diarrhea. The most commonly diagnosed causes of pneumonia in nursing, growing, and finishing pigs were *Pasteurella multocida*, *Mycoplasma*, and *Actinobacillus* (*Haemophilus*) *pleuropneumoniae*. *Streptococcus* and *Salmonella* were common causes of bacterial septicemia in Kansas pigs.

(Key Words: Disease, Diagnosis, Diarrhea, Pneumonia.)

Introduction

Enteric and respiratory diseases account for large economic losses to the swine industry each year. An accurate diagnosis of the cause is essential for effective prevention and control of these diseases. The present summary was performed to demonstrate the relative importance of various causes of enteric, respiratory, and septicemic diseases as determined at the diagnostic laboratory level.

Procedures

Diagnoses and age were summarized for cases of diarrhea, pneumonia, and bacterial septicemia in pigs from computer records for submissions to the Kansas State University Veterinary Diagnostic Laboratory for fiscal year 1991 (July, 1990 to June, 1991). Specimens included living or dead pigs and/or tissues. A diagnosis was made following light microscopic, bacteriologic, and virologic examination of tissues and summarized in a computer data base.

Results and Discussion

Causes and number of cases of pre- and postweaning diarrhea, pneumonia, and septicemia are summarized in Tables 1 and 2, respectively. In spite of extensive vaccination and effective vaccines for the control of colibacillosis, *E. coli* still remains the most frequent cause of both pre- and postweaning diarrhea in pigs in Kansas. Transmissible gastroenteritis was a much more common cause of preweaning than postweaning diarrhea and frequently recurred in sequential farrowings (endemic or chronic TGE). The highest incidence of coccidiosis was in the months of July and August (12/27 cases). Proliferative enteritis (terminal ileitis) is an important cause of diarrhea in Kansas swine herds. Cases of diarrhea with an idiopathic diagnosis were those for which no cause could be determined by routine laboratory testing. The primary reasons for no diagnosis in cases of diarrhea were 1) submitting tissues from pigs too late in the disease process, 2) advanced postmortem change in submitted tissues, and 3)

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improper tissue collection by the referring veterinarian.

Pasteurella multocida, *Mycoplasma*, and *Actinobacillus* (*Haemophilus*) *pleuropneumoniae* were the most commonly diagnosed causes of respiratory disease in pigs (Table 3). Frequently more than one bacterial species was isolated from the same lung. Antibiotic treatment is one likely explanation for the large number of idiopathic diagnoses. Additionally, some lungs were submitted fixed in formalin, with no unfixed tissue available for bacterial culturing.

Steptococcus and *Salmonella* were the most common causes of bacterial septicemia in Kansas pigs, accounting for 33.3 and 26.7% of all cases, respectively (Table 4).

Table 1. Causes of Preweaning (< 3 Weeks of Age) Diarrhea in Pigs for Submissions to the KSU Veterinary Diagnostic Laboratory (July, 1990 to June, 1991)

Cause/Disease	No. cases	% of total cases
E. coli	55	33.4
TGE	40	24.4
Isospora suis (Coccidia)	27	16.5
Idiopathic[a]	16	9.8
Rotavirus	8	4.9
Clostridium perfringens type C	7	4.3
Viral[b]	7	4.3
Other	4	2.4
Total	164	100.0

[a]Exact cause of the diarrhea could not be determined.
[b]Microscopic intestinal changes were consistent with a viral diarrhea, but a virus was not identified by routine testing.

Table 2. Causes of Postweaning (≥ 4 weeks of age) Diarrhea in Pigs for Submissions to the KSU Veterinary Diagnostic Laboratory (July, 1990 to June, 1991)

Cause/Disease	No. cases	% of total cases
E. coli 30	25.0	
Proliferative enteritis (Terminal ileitis)	23	19.2
Salmonella	16	13.3
Idiopathic[a]	9	7.5
Swine dysentery	8	6.7
Non-specific colitis	8	6.7
TGE	7	5.8
Necrotic enteritis[b]	7	5.8
Hemorrhagic bowel syndrome	5	4.2
Viral[c]	4	3.3
Rotavirus	3	2.5
Total	120	100.0

[a]Exact cause of the diarrhea could not be determined.
[b]No cause was identified, but often the end result of *Salmonella* infection or swine dysentery.
[c]Microscopic intestinal changes were onsistent with a viral diarrhea, but a virus was not identified by routine testing.

Table 3. Causes of Pneumonia in Nursery, Growing, and Finishing Pigs for Submissions to the KSU Veterinary Diagnostic Laboratory (July, 1990 to June, 1991)

Cause/Disease	No. cases[a]	% of total cases
Mycoplasma	44	21.2
Pasteurella multocida	42	20.2
Actinobacillus (*Haemophilus*) *pleuropneumoniae*	24	11.5
Idiopathic[b]	23	11.0
Streptococcus suis	22	10.6
Streptococcus (not *suis*)	19	9.1
Bordatella bronchiseptica	5	2.4
Swine influenza	4	1.9
Other bacterial	23	11.0
Misc.	2	1.0
Total	208	100.0

[a]Isolates were from approximately 150 different submissions.
[b]Exact cause of the pneumonia could not be determined.

Table 4. Causes of Septicemia in Nursery, Growing, and Finishing Pigs for Submissions to the KSU Veterinary Diagnostic Laboratory (July, 1990 to June, 1991)

Cause/Disease	No. cases	% of total cases
Streptococcus (not *suis*)	20	33.3
Salmonella	16	26.7
Edema disease	8	13.3
Streptococcus suis	6	10.0
Erysipelas	6	10.0
Other	4	6.7
Total	53	100.0

EFFECTS OF SUPPLEMENTATION OF NURSERY DIETS WITH AN ESSENTIAL FATTY ACID ON IMMUNITY IN ARTIFICIALLY REARED PIGS

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Summary

Twenty four pigs were weaned immediately at farrowing, reared artificially for 21 d, and then used in a 35-d nursery experiment to determine the effects of essential fatty acid deficiency on immune function. Treatments were: 1) a semi-purified diet deficient in essential fatty acids and 2) diet 1 with 2% added linoleic acid. Conversion of linoleic acid to linolenic and then arachidonic acid is a normal step in fatty acid metabolism. Metabolites of arachidonic acid are thought to have a role in mediating immune function. On d 28 of the experiment, pigs were orally dosed with *Salmonella choleraesuis* to challenge their immune systems. At d 35, pigs fed linoleic acid had greater concentrations of several fatty acids in both small intestine and liver tissues. Also, several measures of arachidonic acid metabolites in the plasma, which activate inflammatory reactions and stimulate white blood cell activity, were greater for pigs fed diets with added linoleic acid. However, no gross lesions were noted at necropsy that would result from infection with *S. choleraesuis*. Thus, for the short period of this experiment (35 d), deficiency of essential fatty acids apparently had minimal effect on ability of nursery pigs to resist disease.

(Key Words: Starter, Essential Fatty Acid, Immunity, *Salmonella choleraesuis*.)

Introduction

Swine producers are well aware of the stressful period that pigs experience at weaning, with the abrupt changes in environment, social structure, and diet. These stressors are especially problematic because the pigs no longer have access to the passive immunity supplied by antibodies from sow's milk, combined with a relatively undeveloped immune system in the pigs themselves. Researchers focused primarily on the use of antibiotics and vaccines to assist weanling pigs during this time of stress, until recent advances in the use of specialty diets (e.g., with 30 to 60% milk products, emulsified and blended fats, dried plasma protein, specialty soybean products, etc.) stimulated interest in manipulation of dietary ingredients to facilitate early weaning with minimum morbidity and mortality.

One area of interest common to veterinarians and nutritionists results from the understanding that the essential fatty acids (linoleic, linolenic, and arachidonic acid) are precursors for prostaglandins that mediate activity of the immune system. The experiment reported herein was designed to determine the potential for improving immune function in compromised pigs by addition of an essential fatty acid to their diets.

Procedures

Twenty-four pigs were removed from sows immediately at birth and orally dosed with

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porcine blood plasma to ensure consumption of antibodies without exposure to possible disease organisms from the sows. The pigs were housed in isolation for 21 d and given a diet of canned milk. At d 21, the pigs were moved to individual cages in a disease control facility and given the experimental diets (Table 1) for 35 d. The two diets were: 1) a semi-purified control diet, formulated to be nearly devoid of fat (.45%) and essential fatty acids; and 2) diet 1 with 2% linoleic acid (20 × the published NRC requirement) added at the expense of cornstarch.

Blood samples were collected 2 d before and 27 d after initiation of feeding the experimental diets (i.e., start of the experiment). On d 28 of the experiment, the pigs were challenged by oral infusion with viable *S. choleraesuis* organisms. Blood samples were collected on d 32 and 35. Pigs were euthanized on d 35 for collection of tissue from the small intestine and liver. The intestines, spleen, liver, lungs, and mesenteric lymph nodes were examined for lesions associated with *S. choleraesuis* infection and scored on a scale from 1 (no symptoms) to 3 (moderate to severe lesions). Response criteria were plasma concentrations of protein, albumin, leukotriene B_4 (LTB_4), prostaglandin E_2 (PGE_2) and thromboxane B_2 (TXB_2); white blood cell counts; neutrophil chemotaxis; neutrophil chemiluminescence; neutrophil synthesis of eicosanoids; fatty acid concentrations in the small intestine and liver; and severity of lesions in the intestines, spleen, liver, lungs, and mesenteric lymph nodes.

Table 1. Diet Composition[a]

Ingredient,%	Deficient diet
Cornstarch	38.98
Soy protein isolate	14.70
Dried skim milk	20.00
Dried whey (edible grade)	20.00
Cellulose (solka-floc)	3.00
Monocalcium phosphate	1.88
Limestone	.44
Salt	.10
Vit/Min mix	.52
Lysine-HCl	.13
Chromic oxide	.25

[a]For the diet with adequate essential fatty acid concentration, 2% linoleic acid was used in place of cornstarch.

There were no tissue by treatment inter

Results and Discussion

Intestine tissue had greater concentration of myristic acid and numerically greater amounts of palmitoleic and linoleic acid than liver tissue (Table 2). Liver tissue had greater concentrations of palmitic, stearic, oleic, linolenic, and arachidonic acid than intestine tissue.

There were no tissue by treatment interactions, indicating that the slight increases in fatty acid concentrations for pigs fed the diet with added linoleic acid were consistent in the intestine and liver. When pooled across tissues (intestine and liver), feeding diets with adequate linoleic acid resulted in numerical increases in concentrations of all fatty acids, with statistically significant increases for palmitoleic and oleic acid. These data indicate that diets deficient in essential fatty acids and nearly devoid of any fat tend to reduce fatty acid concentrations in tissues of nursery pigs. However, large changes in fatty acid concentrations were not observed, indicating that pigs had substantial reserves of fatty acids after artificial rearing to 21 d of age with canned milk.

Plasma concentrations of total protein, albumin, and TXB_2 were greater at d 27 for pigs fed the adequate diet compared to pigs fed the diet that was deficient in essential fatty acids (Table 3). These changes suggest that deficiency of essential fatty acids impares protein synthesis in the liver. Plasma concentrations of the arachidonic acid metabolites LTB_4, PGE_2, and TXB_2 were greater at d 32 (after challenge) for pigs fed the adequate diet than pigs fed the deficient diet. These compounds activate inflammatory reactions and stimulate white blood cells to recognize and destroy infectious microorganisms. However, these advantages in plasma concentrations of arachidonic acid metabolites could not be correlated with increased synthesis in isolated white blood cells (Table 4). Total and differential white blood cell counts were not different for pigs fed the experimental diets. No differences were noted for the ability of white blood cells to migrate toward infectious organisms (chemotaxis). Luminol-dependent chemiluminescence (a measure of white blood cells ability to kill) decreased significantly in all pigs after *S. choleraesuis* challenge, but pigs fed the adequate diet had four times the activity at d 35 compared to pigs fed the deficient diet (Figure 1).

Apparently, the attempt at moderate infection by oral challenge with *S. choleraesuis* was met with sufficient immune function by pigs in both treatment groups to prevent all but minimal pathological tissue damage. At necropsy, the only tissue reactions observed were indicative of mild inflammation that cleared the infecting organisms. There were no differences in frequency or severity of lesions for pigs fed the adequate or deficient diets. This observation is consistent with effective white blood cell function in both groups.

These data indicate that diets deficient in essential fatty acids and nearly devoid of fat tend to reduce fatty acid concentrations in tissues of nursery pigs. However, wholesale changes in fatty acid concentrations were not observed, indicating that pigs had substantial reserves of fatty acids after artificial rearing to 21 d with canned milk. Furthermore, although the pigs fed adequate diets had small advantages in some measures of immune function (i.e., plasma concentrations of total protein, albumin, LTB_4, PGE_2, and TXB_2), pigs in both treatment groups were able to thwart attempts at inducing a mild infection with *S. choleraesuis*. Thus, short-term deficiency of essential fatty acids (i.e., for a 35-d nursery experiment) appears to have minimal effect on immune function of artificially reared pigs.

Table 2. Effect of Feeding a Diet Deficient in Essential Fatty Acids on Fatty Acid Profiles of the Small Intestine and Liver

	Small intestine		Liver		
Fatty acid, % of tissue wt	Deficient	Adequate	Deficient	Adequate	CV
Myristic (14:0)[d]	.07	.09	.04	.05	56.7
Palmitic (16:0)[a]	2.29	2.67	2.76	2.93	25.2
Palmitoleic (16:1)[f]	.70	.76	.51	.73	32.1
Stearic (18:0)[d]	1.79	2.19	3.67	3.57	27.4
Oleic (18:1)[ae]	4.06	4.91	4.96	5.31	24.3
Linoleic (18:2)[g]	1.55	1.68	1.48	1.52	32.3
Linolenic (18:3)[b]	.44	.47	.11	.28	103.3
Arachidonic (20:4)[c]	2.42	2.49	3.57	3.51	37.3

[abcd]Intestine vs liver (P<.10, P<.05, P<.01, P<.001, respectively).
[ef]Deficient vs adequate (P<.10, P<.05, respectively).
[g]No treatment effect (P>.44).

Table 3. Clinical Chemistry

Item	Deficient diet	Adequate diet
Total protein, g/dl (d 27)[a]	3.9 ± .51	4.5 ± .36
Albumin, g/dl (d 27)[a]	2.3 ± .42	2.8 ± .16
Leukotriene B_4, pg/100 µL (d 32)[a]	6.3 ± .8	10.8 ± 1.1
Prostaglandin E_2, pg/100 µL (d 32)[a]	80 ± 21	112 ± 15
Thromboxane B_2, ng/100 µL		
d 2	.8 ± .2	1.2 ± .3
d 27[a]	.9 ± .1	2.7 ± .4
d 32[a]	.9 ± .4	2.4 ± .1

[a]Effect of diet treatment (P<.05).

Table 4. White Blood Cell (Neutrophil) Synthesis of Eicosanoids (In Vitro), Day 27[a]

		Stimulant	
Metobolite	Treatment diet	Phorbolmyristic acid	A23187, calcium ionophore
LTB_4	Deficient	1.14	1.64
LTB_4	Adequate	1.27	1.87
PGE_2	Deficient	1.34	1.14
PGE_2	Adequate	1.74	1.69
TXB_2	Deficient	1.21	1.06
TXB_2	Adequate	1.10	.94

[a]All concentrations are total pg of metabolite secreted into 1.0 ml of medium. There were no differences (P>.05).

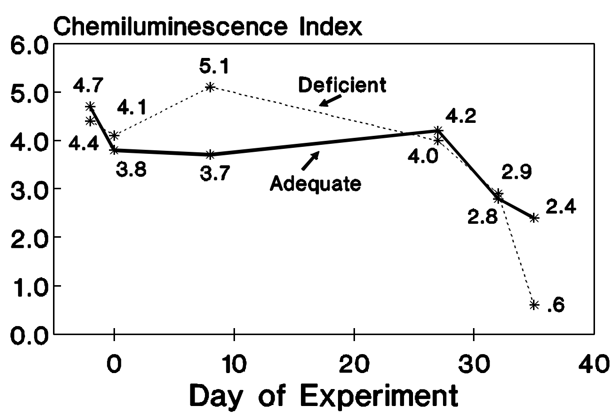

Figure 1. Chemiluminescence of White Blood Cells (Neutrophils).

USE OF RECOMBINANT BOVINE CYTOKINES IN PIGS VACCINATED AND CHALLENGED WITH STREPTOCOCCUS SUIS

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***and J. L. Nelssen*[3]**

Summary

An experiment was conducted to determine the adjuvanticity of recombinant bovine interleukin-1ß (rBoIL-1ß) and recombinant bovine interleukin-2 (rBoIL-2) administered in conjunction with a single *S. suis* vaccination in pigs. Sixty, 4-wk-old pigs were allotted to 8 groups: 1) nonvaccinated controls; 2) vaccinated controls; 3) rBoIL-1ß, 100 ng/kg; 4) rBoIL-1ß, 1000 ng/kg; 5) rBoIL-1ß, 10,000 ng/kg; 6) rBoIL-2, 2.5 µg/kg; 7) rBoIL-2, 25 µg/kg; and 8) rBoIL-2, 250 µg/kg. All pigs (except group 1) were vaccinated on d 0 with a commercial *S. suis* vaccine (serotypes 1 and 2). At vaccination, pigs were injected intramuscularly with their respective cytokine treatments. Pigs received additional cytokine injections for 2 consecutive days. On d 21, all pigs were injected intravenously with 3.5×10^9 CFU of a log phase culture of *S. suis* (serotype 2). The highest dose of rBoIL-1ß exceeded the maximum tolerable dose for the cytokine; however, this dose of rBoIL-1ß protected pigs from the *S. suis* challenge. In pigs receiving rBoIL-1ß at 10,000 ng/kg, pathological lesions caused by *S. suis* were lowest when compared to other treatment groups. No mortality from *S. suis* challenge was observed in pigs that received the highest dose of rBoIL-1ß. These data clearly show that rBoIL-1ß (10,000 ng/kg), administered intramuscularly for 3 consecutive days at vaccination, is more effective than the *S. suis* vaccine alone in protecting pigs against a *S. suis* challenge.

(Key Words: Cytokine, Adjuvant, Pig, Vaccine.)

Introduction

Cytokines, particularly interferon gamma, interleukin-1 (IL-1), and IL-2, have been used successfully as adjuvants in several species. In pigs, recombinant porcine interferon gamma has been used in an effort to reverse dexamethasone-induced immunosuppression. Although recombinant porcine IL-1 IL-2 have been cloned and expressed, they are not available for in vivo use. Human recombinant IL-2 has been evaluated both as a nonspecific immunomodulator and as an adjuvant in pigs. We have shown that recombinant bovine IL-1ß (rBoIL-1ß) and rBoIL-2 can be effective adjuvants to bovine herpesvirus-1 vaccination in cattle. It is likely that they also will be effective adjuvants in pigs.

Infection in pigs caused by *Streptococcus suis* is a widespread problem of the swine industry in the major swine-producing countries of the world. In the United States, awareness of the severity of *S. suis* infection has been relatively slow. However, in recent years there has been an increase in reports of *S. suis* infection in all ages of pigs, frequently causing meningitis, septicemia, pneumonia, and arthritis.

The widespread prevalence of *S. suis* infections has necessitated extensive research efforts on prevention and control measures. Bacterins have been used in the United States for the prevention of

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[1]Department of Anatomy and Physiology.
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[3]We thank American Cyanamid Co., Princeton, NJ, for providing the cytokines and partial financial support for this project.

S. suis infection with some success. However, the rising incidence of *S. suis*, and the economic impact that this agent imposes on the swine industry makes the development of suitable vaccination programs imperative to control the disease. Therefore, the objective of this study was to determine if rBoIL-1ß and rBoIL-2 used in conjunction with a **single** *S. suis* vaccination increase immunity and resistance to a homologous *S. suis* challenge.

Procedures

Sixty, 4-wk-old pigs from a herd with no known history of *S. suis* were used. Eight pigs (except Group 1) were allotted by weight and gender to one of the following 8 groups: Group 1: nonvaccinated controls (4 pigs); Group 2: vaccinated controls; Group 3: vaccinated + rBoIL-1ß at 100 ng/kg; Group 4: vaccinated + rBoIL-1ß at 1,000 ng/kg; Group 5: vaccinated + rBoIL-1ß at 10,000 ng/kg; Group 6: vaccinated + rBoIL-2 at 2.5 µg/kg; Group 7: vaccinated + rBoIL-2 at 25 µg/kg; Group 8: vaccinated + rBoIL-2 at 250 µg/kg. At the start of the experiment (d 0), pigs were vaccinated intramuscularly with a commercial *S. suis* vaccine (Oxford Laboratories, types 1 and 2). At vaccination, pigs were injected intramuscularly with their respective cytokine treatment. Pigs received additional cytokine injections for 2 consecutive days. On d 21, all pigs were injected intravenously with 3.5×10^9 colony forming units of a log phase culture of *S. suis* type 2. Pigs were weighed weekly and body weights recorded. Pigs were observed daily following challenge (early morning), and the following clinical signs were recorded: dyspnea, nasal discharge, depression, lameness, and CNS disorders. Rectal temperatures were recorded daily from d 21 through 28. All pigs were euthanized by electrocution on d 28, and gross lesions, including meningitis, pleuritis, pericarditis, peritonitis, synovitis, and pneumonia (lung weight/body weight), were scored and recorded.

Results and Discussion

Depending on the dosage, in vivo use of rBoIL-1ß and rBoIL-2 caused dramatic effects on the physiology and immunology of 4-wk-old pigs. Pigs injected with rBoIL-1ß at 10,000 ng/kg displayed profound physiological effects in response to the cytokine treatment. Within 3 hours of injection, pigs showed behavior such as vomiting and lethargy. Continued injections of 10,000 ng/kg rBoIL-1ß caused some pigs to display CNS disturbances (paddling). The adverse effect of the highest dose of rBoIL-1ß was reflected in the poor growth performance in these pigs during the first 2 wk of the study (Table 1). However, as will be discussed later, even though these pigs were very severely affected by the rBoIL-1ß injections, they responded best to the *S. suis* challenge. Their enhanced resistance to *S. suis* is perhaps best shown by their positive average daily gain during the week of infection, when pigs in all other treatment groups were losing weight (Table 1). Pigs that were administered rBoIL-2 did not respond differently than control animals.

Similar to the growth performance data, Table 2 shows data indicating that pigs treated with the highest dose of rBoIL-1ß were least affected by the challenge with *S. suis*. The day after challenge with *S. suis*, pigs in all treatment groups showed similar clinical signs of disease. However, on d 2 postchallenge, pigs treated with rBoIL-1ß at 10,000 ng/kg were less affected clinically compared to control pigs. The trend for pigs from the highest dose rBoIL-1ß treatment group to have lower clinical signs of disease continued throughout the experiment. Because 3 out of 8 control pigs died by d 3, the difference in clinical signs between the control pigs and the highest dose rBoIL-1ß pigs (no deaths) is certainly biased in favor of no treatment effect. Pigs treated with the highest dose of rBoIL-1ß did not die when challenged with *S. suis* (Table 3). Pathological lesions caused by *S. suis* were lowest in pigs that received rBoIL-1ß as a vaccine adjuvant when compared to values from control pigs (Table 3).

These data clearly show that rBoIL-1ß (10,000 ng/kg), administered intramuscularly for 3 consecutive days at vaccination, is more effective than the *S. suis* vaccine alone in protecting pigs against a *S. suis* challenge. Pigs treated with the highest dose of rBoIL-1ß had less severe clinical signs of the disease after challenge, better growth performance during the infection, and less severe pathological lesions caused by the bacteria. Also, no pigs in this treatment group died from the bacterial challenge. However, 10,000 ng/kg of rBoIL-1ß cannot be administered to pigs because of the adverse reaction to the cytokine at the time of administration. Clearly, it would be beneficial to find a dosage of rBoIL-1ß between 1,000 and 10,000 ng/kg that produced the same positive results as the highest dose of the cytokine but without adverse effects at the time of administration. Considering the encouraging results of this study, these possibilities should be explored.

Table 1. Average Daily Gain (lb) of Pigs Vaccinated and Challenged with *S. suis* and Administered rBoIL-1ß or rBoIL-2 as Adjuvants at Vaccination

	----------Treatment----------								
		rBoIL-1ß (ng/kg)			rBoIL-2 (				
Period (day)	Control	100	1,000	10,000	2.5	25	250	SE	Prob.
0-7	.64[a]	.59[a]	.68[a]	.26[b]	.64[a]	.51[a]	.57[a]	.03	.001
0-14	.84[ab]	.77[a]	.84[a]	.66[b]	.84[a]	.68[ab]	.79[ab]	.03	.06
0-21	.92[ab]	.90[ab]	.97[a]	.79[ab]	.95[ab]	.77[b]	.86[ab]	.03	.05
21-28	-.33[a]	-.18[ab]	-.09[ab]	.29[b]	-.04[ab]	-.31[a]	-.15[a]	.11	.07
0-28	.66[ab]	.66[ab]	.73[a]	.66[ab]	.68[ab]	.51[b]	.57[ab]	.03	.03

Pigs were vaccinated on d 0 and administered cytokines on d 0, 1, and 2. All pigs were challenged with *S. suis* 21 d after vaccination. Values are least squares means, n=8. [ab]Means within rows not sharing common superscripts differ.

Table 2. Pooled Clinical Signs of Pigs Vaccinated and Challenged with *S. suis* and Administered rBoIL-1ß or rBoIL-2 as Adjuvants at Vaccination

	---Treatment---								
			rBoIL-1ß (ng/kg)			rBoIL-2 (			
Day	Nonvaccinates	Control	100	1,000	10,000	2.5	25	250	SE
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	8.0	7.3	9.3	8.1	7.5	7.4	9.9	7.5	.9
2	7.0	8.3[a]	5.7[ab]	7.3[ab]	5.1[b]	7.6[ab]	7.5[ab]	7.4[ab]	1.1
3	5.5	6.2[ab]	5.9[ab]	5.3[ab]	3.1[a]	5.3[ab]	8.7[b]	6.5[ab]	1.2
4	6.3	6.2[ab]	4.4[ab]	3.4[ab]	2.8[a]	4.8[ab]	7.2[b]	5.0[ab]	1.2
5	6.3	2.8	4.3	3.6	1.3	3.5	4.8	1.8	1.3
6	3.0	2.0[ab]	3.0[ab]	2.4[ab]	1.4[a]	1.8[ab]	4.7[b]	1.2[ab]	1.1
7	2.0	2.0	1.7	3.4	1.8	1.0	3.2	.83	.9

All pigs were challenged with *S. suis* 21 d (d 0) after vaccination. Scoring = 0 to 3 (normal to severe) for dyspnea, nasal discharge, depression, and CNS disorders; 0 to 4 (normal to down) for lameness; and 0 to 5 (normal to > 107 for rectal temperature. Values are least squares means. [ab]Means within rows not sharing common superscripts differ (P<.05).

Table 3. Mortality and Necropsy Findings of Pigs Vaccinated and Challenged with *S. suis* and Administered rBoIL-1ß or rBoIL-2 as Adjuvants at Vaccination

	---Treatment---								
			rBoIL-1ß (ng/kg)			rBoIL-2 (			
Item	Nonvaccinates	Control	100	1,000	10,000	2.5	25	250	SE
Mortality (%)	25.0	37.5	25.0	37.5	0.0	25.0	25.0	25.0	--
Necropsy Score	7.55	7.88[a]	5.14[b]	5.12[b]	5.00[b]	6.14[a]	7.14[a]	7.00[a]	.92
Lung Weight/ Body Weight (%)	1.59	1.65	1.57	1.72	1.27[c]	1.46	1.42	1.48	.16

All pigs were challenged 21 d after vaccination with *S. suis* and necropsied at death or 7 d after challenge. Necropsy scoring = 0 to 2 (normal to severe) for pleuritis, pericarditis, meningitis, and peritonitis and 0 to 4 (normal to severe) for synovitis. Values are least squares means. [ab]Means within rows not sharing common superscripts differ (P<.05). [c]Control vs. 10,000 ng/kg rBoIL-1ß, P=.10.

EVALUATION OF A ROTATING DRUM MIXER[1]

C. R. Stark[2], K. C. Behnke[2], and C. H. Fahrenholz[2]

Summary

A "rotating drum" type mixer was tested to determine if it could produce a uniformly mixed feed. Feed was manufactured in four separate trials, which examined addition sequence, mixing time, mixer capacity, and liquid addition. Uniformly mixed feed was obtained after 8 min, when ingredients were properly sequenced and mixed. Smaller batch sizes decreased the time required to obtain a uniform mixture. The mixer distributed liquid uniformly through the feed and had excellent clean-out capabilities.

(Key Words: Rotating Drum Mixer, Feed Uniformity, Feed Manufacturing, Mixer Testing.)

Introduction

Properly designed mixers have the potential to produce uniformly mixed feed. However, the time required to produce a uniform mixture varies between mixer classes. Mixers also vary considerably within a class. Therefore, it is essential that all mixers be evaluated for their ability to produce a uniformly mixed feed, time required to produce a uniform mixture, and completeness of clean-out.

Rotating drum mixers have become increasingly popular for farm applications. Low energy consumption, good clean-out, and the ability to produce uniformly mixed feed has made these mixers popular. Because of their increased use and the lack of information on these mixers, a study was needed to evaluate their ability to produce uniformly mixed feed. The study was designed to determine the appropriate mixing time, proper ingredient sequence, batch size, clean-out, and liquid application for a "rotating drum-mixer.

The study was divided into four trials. Trials I and II investigated the effect of ingredient sequence addition on mixing time. Trial III examined uniformity of partial batches and liquid addition. Trial IV determined mixing time required from a dead stop after ingredient addition.

Procedures

Mixer uniformity tests were performed on a drum mixer with a capacity of 38 ft^3 and rotating at 7 RPM. Sequence of ingredient additions in Trial I was sorghum, soybean meal, wheat midds, and premix.

The sequence was reversed in Trial II. Trial III sequence was soybean meal, premix, wheat midds, and sorghum. In each trial, the assay ingredient, salt, was included in the premix.

A sow diet with an apparent bulk density of 36.25 lb/ft^3 was used for all mixer uniformity tests (Table 1). Ingredients were added to the mixer while the drum was rotating in Trials I through III. A 4 in. screw conveyor was used to fill the mixer. Fill time was between 8 to 10 min for the 1500 lb batch. Mix times began after the last ingredient addition. The mixer was stopped and sampled at designated times (Tables 2 and 3). Ten, 50-g samples were obtained from the same

[1]A special thanks to the 1991 Feed Technology II class for helping conduct the research.
[2]Department of Grain Science and Industry.

location in the mixer each time it was stopped. Samples were analyzed for salt content with the Quantab[R] Chloride Ion test. Coefficient of variation (CV) values < 10% indicate a uniformly mixed feed for the Quantab[R] Chloride Ion test.

Trial III involved production of 500-, 1000-, and 1500-lb batches of feed. The feed was sampled at 4, 8, 12 min and discharge. Choice white grease (2.9%) was applied to the 1500 lb batch of feed after it was dry mixed for 12 min. The feed was mixed for an additional 5 min after the fat was added. Samples for crude fat analysis were taken at the discharge.

Ingredients were placed in the mixer without the drum rotating in Trial IV. The mixer was started after the last ingredient and sampled at 4, 8, 12 min and discharge.

Results and Discussion

Results for mixing time are presented in Table 2 for Trials I and II. When the premix was added last, mixing time required to obtain a uniform mixture was not accomplished until discharge (11 min). When the premix was added first, 8 min were required to produce a uniform feed. The table indicates that the feed was uniform at 1, 2, and 4 min, but visual examination as well as variablity between replications indicated that the mixer did not consistently produce a uniform feed at those times. In addition, adding the premix first caused problems with dead spots and premix loss.

Trial III showed that adding the premix second resulted in a uniform mix after 8 min (Table 3). In addition, it eliminated mixer dead spots and premix loss. The results also indicate that rotating drum mixers can mix batches that are less than rated capacity. Mixing time decreased as batch size decreased.

The fat was evenly applied throughout the 1500 lb batch. Crude fat analysis ranged from 3.28 to 3.64% on 10 samples. The results indicate that the mixer is capable of uniformly distributing liquids.

Starting a 1000 lb batch from a dead stop after all ingredients were added produced a uniformly mixed feed after 8 min. At 4 min, the coefficient of variation was 11%, when <10% is desired. Therefore, a uniform feed can be produced between 4 and 8 min from a dead stop.

The study indicates that rotating drum mixers are capable of producing a uniform batch of feed when used properly. With the type of mixer used in the present study, uniform feed can be produced after 8 min. Mixing time can vary between mixers; therefore, it is necessary to test every new mixer. Mixers should be tested annually to determine if current mixing procedures are satisfactory. Factors such as equipment condition, ingredient sequence, batch size, ingredient particle size, and density all affect mix time.

Table 1. Sow Diet

Ingredients	Percentage
Ground Sorghum	66.35
Soybean meal 44%	15.00
Wheat midds	15.00
Dicalcium phosphate	1.60
Limestone	1.20
Salt	.50
Vitamin premix	.25
Trace mineral premix	.10

Table 2. Calculated CV's (%) for Ingredient Addition Sequence

Mix Time (min)	Trial I[a]	Trial II[b]
1	111.93	9.82[d]
2	74.83	8.00[d]
4	35.26	9.51[d]
8	11.96	8.46
Discharge[c]	9.99	6.21

[a]Sequence sorghum, SBM, wheat midds, premix.
[b]Sequence premix, wheat midds, SBM, sorghum.
[c]Discharge rate of 500 lb/min.
[d]Visial inspection of the feed and variablity between replications indicated that feed may not be consistently uniform at these times.

Table 3. Calculated CV's (%) for Different Batch Sizes and Starting from a Dead Stop

	Batch Size[a]			
Mix Time (min)	500 lb	1000 lb	1500 lb	Dead Stop[b]
4	6.13	5.82	7.50	11.11
8	9.21	7.12	5.66	6.21
12	8.88	6.05	6.93	5.05
Discharge	8.27	7.66	7.45	7.27

[a]Ingredients were added while the mixer was rotating.
[b]Ingredients added prior to starting the mixer.

ON-FARM FEED UNIFORMITY SURVEY

C. R. Stark[1,2], K. C. Behnke[2],
R. D. Goodband, and J. A. Hansen

Summary

An on-farm feed manufacturing survey was conducted in conjunction with a mixer uniformity analysis. The survey collected information on producer size and type of operation, mixer type, manufacturing practices, and feed production. The survey represents 43 participants from across the U.S. Results indicate that 42% of the participants had mixer uniformity coefficients of variation of less than 10%, 47% were between 10-20%. and 11% had CV's greater than 20%.

(Key Words: On-Farm Feed Manufacturing, Feed Uniformity, Mixers.)

Procedures

Mixer analysis kits were sent out upon request to producers to test their mixing efficiency. The producer had to obtain 10 samples at evenly spaced intervals as the feed was removed from the mixer. In addition, each producer had to complete a survey form. Information was collected on producer size and type of operation, mixer type, manufacturing practices, and feed production.

The samples were analyzed for uniformity of salt distribution by the Quantab[R] Ion strip test. Coefficient of variation (CV) was calculated for each producer. When using the Quantab[R] Ion test, CV's less than 10% indicated a uniformly mixed diet (a CV of 10% takes into account sampling errors and analytical errors).

Results and Discussion

Results indicate that a majority of on-farm feed manufacturers may not be producing a uniformly mixed feed (Table 1) with desired CV's of less than 10%. Non-uniformity beomes more critical when medicated feed additives are included in the feed. The survey indicated that production size had no significant effect on uniformity results. Results did not favor any particular mixer type.

Feed uniformity can be improved by proper ingredient sequencing. A proper ingredient sequence would be: protein soure, premix, flush after the premix (protein source or ground grain), then grain. Grinding to a particle size of less than 800 microns also will help improve feed uniformity. Periodic inspec-

[1]To obtain a mixer analysis kit send your name and address to:

Charles Stark
Shellenberger Hall
Kansas State University
Manhattan, KS 55606

[2]Department of Grain Science and Industry.

tion and repair of worn equipment will help prevent poor feed uniformity. Finally, mixers should be tested annually to determine if the feed manufacturing protocol is sufficient or if it should be changed. However, the first step is to develop a feed manufacturing protocol that assures a uniform feed.

Table 1. Results of Mixer Uniformity Analysis for Each Mixer Type

	Coefficient of Variation[a]		
Mixer Type	<10 %	10-20 %	20+ %
Vertical Portable	13	13	3
Vertical Stationary	1	1	1
Horizontal Paddle	2	2	--
Horizontal Double Ribbon	2	--	1
Drum	--	2	--
Other	--	2	--
Total	18	20	5

[a]A coefficient of variation less than 10% indicates a uniformly mixed diet.

EVALUATION OF A PORTABLE MIXER AND FEED DELIVERY SYSTEM[1]

C. R. Stark[2], K. C. Behnke[2], and R. D. Goodband

Summary

An on-farm mixer uniformity study was conducted to determine if feed could be properly mixed and maintained as it went through a bulk bin and conveying equipment over a distance of 180 ft. in a grower-finisher facility. A portable vertical mixer was tested and found to produced a uniformly mixed feed. Uniform feed was then conveyed from a bulk storage bin to feeders inside the facility. Samples were obtained from three different feeders and were tested for uniformity. Results indicate that feed remains uniform as it is conveyed and deposited in feeders over distances of 20, 80, and 180 ft.

(Key Words: On-the-Farm Feed Manufacturing, Portable Mixers.)

Introduction

Providing uniformly mixed feed to pigs helps assure that they receive nutrients in the correct proportion. On-farm mixer uniformity has become a concern, as more and more swine producers begin to manufacture their own feed. This concern becomes even greater when small inclusion levels of medicated feed additives are used. In the past, the commercial feed manufacturing industry has done most of the work on feed uniformity. Quality feed manufacturers routinely check their mixer to assure that a uniform mixture is being produced. Producers who mix their own feed assume this responsibility, as well as the Good Manufacturing Practices of the Food and Drug Administration when medicated feed additives are used. This study was conducted to determine if a new, portable, on-farm mixer could produce a uniformly mixed feed. In addition, uniformity of feed was examined after it was conveyed from a bulk bin to the feeders over a distance of 180 ft. in a grower-finisher facility.

Procedures

A field study was performed over 3 consecutive weeks, starting with an empty bulk bin and feeders. A 6500-lb batch of feed was manufactured in a new, portable, grinder-mixer. Ingredients were added to the mixer in the following order: soybean meal, base mix, medicated feed additive, lysine, and sorghum (1/8" screen). Ingredient addition, grinding, and mixing times were recorded (Table 1).

Samples were obtained as the mixer emptied into the bulk bin. Ten samples were obtained at about 500 lb intervals after 1000 lb were removed from the mixer. Ten samples 30 sec apart were obtained at feeders 1, 5, & 11 (20, 80, and 180 ft., respectively; Figure 1) as feed was conveyed from the bulk bin to the feeders by a flex-auger system.

All samples were analyzed for salt content using Quantab^R Ion strips. A coefficient of variation was calculated for the mixer and each feeder location. Coefficient of variation (CV) = standard deviation/mean X 100. When the Quantab^R Ion strip test is used, CV's less than 10% indicate a uniformly mixed feed (a CV of 10% takes into account sampling errors and analytical errors).

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[1]We thank Ken Goodyear, Pioneer Pork, Dewight, KS for assistance in conducting the study.

[2]Department of Grain Science and Industry.

Results and Discussion

The portable vertical mixer produced a uniformly mixed feed (Table 2) each week with the ingredient additionand mixing times used by the producer (Table 1). The ability to produce a uniform mixture depends on equipment condition, ingredient sequence, and particle size. These will vary among producers.

Conveying feed through a 180 ft flex-auger system did not affect the uniformity of feed deposited in the feeders. Salt remained uniformly distributed from the bulk bin to the feeders (Table 2). In the study, the conveying system produced little segregation. One should also bear in mind that conveying systems do not have the capability of mixing an improperly mixed feed; therefore, it is essential tostart with a uniform feed in the bulk storage bin. Many factors are involved in obtaining a uniform feed mix, such as type and condition of equipment, mixing/grinding time, particle size, and ingredients. Every producer should develop a feed manufacturing protocol that assures a uniform feed.

The results of this study indicate that a uniformly mixed feed will remain uniform as it is conveyed to feeders in a grower-finisher facility.

Table 1. Ingredient Addition, Grinding, and Mixing Times (min)

Replication	Premix[a]	Grinding	Mixing	Unloading
1	---	12.0	4.0	6.0
2	3.6	12.3	3.0	6.0
3	2.5	12.2	3.0	6.0

[a]Base mix, medicated feed additive, lysine.

Table 2. Coefficient of Variation (%) Results for the Mixer and Feed Delivery System[a]

Replication	Bulk Bin	Feeder #1[b]	Feeder #5	Feeder #11
1	7.90	6.88	9.81	9.34
2	5.28	5.82	7.23	6.42
3	6.85	6.87	6.29	6.04
Average	6.68	6.52	7.78	7.27

[a]A coefficient of variation less than 10% indicates a uniformly mixed batch of feed.
[b]Feeders 1, 5, and 11 were 20, 80, and 180 ft. from the bulk bin, respectively.

Figure 1. Bulk Bin and Conveying System.

PRODUCING HOGS UNDER CONTRACT

Michael R. Langemeier[1]

Summary

Recently, there has been a renewed interest in contract hog production. Contractors are looking for an effective means to expand production or utilize excess feed production capacity. Producers enter contracts to minimize input cost and market risks or to obtain financing for buildings and equipment. Provisions vary from contract to contract. Producers that are making the decision whether to produce hogs under contract should calculate expected returns for a range of production and cost scenarios. Whatever the contract provisions, producers and contractors should make sure that the contract rewards them for what they do best.

(Key Words: Contract, Program, Economics.)

Introduction

There has been an increasing interest in contract hog production in recent years. One of the primary reasons for this is the availability of financing through contracting. In 1988, about 10 to 12 percent of U.S. slaughter was accounted for by contract operations. Glenn Grimes, from the University of Missouri, estimates that the number of contract hogs will increase about 6 to 10 percent annually. Using these estimates contract hog production is expected to account for 23 to 35 percent of U.S. slaughter by the year 2000.

Traditionally, most of the contract production has been concentrated in the East Coast region. There are some indications that contract hog production is becoming more prevalent in the North Central region. For example, an estimated 250,000 hogs will be fed by Murphy Farms alone in north central Iowa this year.

Advantages and Disadvantages of Hog Contracts

Potential contractors include investors, feed dealers, and farmers. Contractors find contract arrangements appealing for several reasons. For example, a contractor may have a large feed production capacity that is currently being less than fully utilized. Contractors may also find contract hog production to be a more effective means of expanding their total hog production. Because the producer (contractee) typically is responsible for facility costs, a contractor can effectively mitigate the financial risk associated with owning facilities. Other reasons why a contractor may find contract hog production appealing relate to the economies of size associated with buying and selling breeding stock and market hogs.

Producers enter a production contract for various reasons. One of the primary reasons is to obtain financing for buildings and equipment. This aspect of production contracts is particularly attractive to young or financially strapped producers with a limited access to capital. Many contractors build the facilities and then provide a loan to the producer. Because feed and pigs are provided by the contractor, producers do not face the risks associated with feed cost and feeder pig changes. In addition, market risk is eliminated because the contractor owns the hogs. Of course, producers that custom feed hogs will not be able to take advantage of high hog prices or low feeder pig and

[1]Department of Agricultural Economics.

feed costs. The fixed payment aspect of most contracts reduces profit and cash flow uncertainty. Production contracts are also attractive to producers that do not want to make the management decisions required to buy inputs and market hogs.

There are disadvantages to hog contracting from both a contractor's and producer's perspective. Contractors that choose the wrong producers may lose a substantial number of hogs or waste an enormous amount of time before the problem is corrected. Producers may find it difficult to save enough money from the fixed payment to build their own facilities. In addition, the contract length may be substantially shorter than the time it takes to pay for the facilities. Producers need to think about how they will pay for the facilities if the contract is terminated.

Types of Contracts

There are many different types of contracts. Payment method, cost sharing, and production bonuses vary from one contract to another. Whatever the contract provisions, producers and contractors should make sure that the contract rewards them for what they do best. For example, production bonuses that are too optimistic will not benefit an above average producer. This producer should seek a contract in which bonuses are paid when production is above average.

Hog finishing contracts are more predominate than contracts for feeder pig and farrow-to-finish production. According to a survey conducted in 1988 by V. James Rhodes at the University of Missouri, 87 percent of contractors contracted pig finishing, 21 percent contracted pig producing, 15 percent contracted farrow-to-finish production, and 3 percent contracted the production of breeding stock.

Many hog finishing contracts guarantee a producer a fixed payment and add or subtract bonuses and discounts from this payment. Bonuses are typically paid for keeping death losses low and feed efficiency high. Discounts are sometimes imposed for high death losses and unmarketable animals. Contract payments can be on a per head basis, a per day basis, or on a per square foot of pig space basis. A common per head payment is $12. Payments on a per day basis typically range from $0.07 to $0.10. Payments on a per square foot of pig space basis may range from $30 to $40 per pig space per year. Payments based on a per pig space basis are attractive from the producer's perspective because, under this contract, less than fully utilized facilities will not add to his/her fixed costs per head.

Under a fixed payment contract for finishing hogs, the producer typically provides the building and equipment, labor, utilities, and insurance. Utilities and insurance are typically around a $1.50 and $0.25 per head, respectively. Assuming an investment cost of $100 per pig space, a facility with a 1,000-pig capacity would cost $100,000. If 2,500 pigs are produced and the interest rate is 11 percent, the annual payment per pig will be about $6.75. If more pigs are produced, the annual payment will be lower. The annual payment will be higher, if less pigs are produced. If the payment is $12 per head, the producer, in this example, will have a return to labor and management of $3.50 per head after subtracting costs.

Characteristics of a Good Contract

Before considering the details of a contract, both parties should consider the reputation of the other party involved in the contract. Some contracts are not easily broken. Thus, it is important to obtain this information before a contract is considered. Like all contracts, the contract should be in written form. Also, the advice of an expert or a lawyer may be useful in evaluating the contract provisions. Contract provisions should include the following:

- the names of both parties;
- the rights and responsibilities of both parties;
- the number of pigs involved;

- the duration of the contract;
- the method and timing of payment;
- the costs to be paid by each party;
- the brands of the feed and supplement;
- a clear statement of how bonuses and discounts will be handled;
- the methods used to calculate performance guidelines;
- how and when the contract may be terminated by either party.

RUNOFF CONTROL FROM DIRT LOTS

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

A recent water quality survey assessment found nonpoint source pollution problems in a majority of Kansas surface waters - 85% of the monitoring sites were impaired by nutrients, 60% of the sites by bacteria, 55% by suspended solids and/or minerals, and 40% by oxygen-demanding substances. Swine producers have the responsibility to maintain the quality of ground or surface water near their production units. Outdoor dirt lots for confinement of swine are often overlooked as an area needing facilities for water pollution control.

Such facilities are dependent upon the size and make-up of a livestock operation, its surface draining characteristics, and the operation's waste management and disposal practices. The Kansas Department of Health and Environment (KDHE) administers the registration, permit, and certification requirements for confined livestock facilities in Kansas. The regulations became law in Kansas on July 1, 1967 and remain in place today. The laws are designed to minimize pollution leaving the vicinity of a confined feeding operation created by normal rainfall, intensive storms, or everyday manure production. The intent of the law is to be able to control, collect, and store the runoff. The collection and storage enable a producer to manage and properly disperse the liquids and nutrients from the production areas onto cropland or pasture.

Confined feeding is defined as confinement of animals in lot or pens, which are not normally used for raising crops and in which no vegetation, intended for animal food, is growing. Swine operations that are utilizing outdoor lots are subject to the regulatory requirements and are required by law to have a waste management plan and permit, if they meet any one of the following operational criteria.

1. The operation has a capacity of 300 or more head of cattle, hogs, or sheep or a combination of all three.

2. The operation, irrespective of size, utilizes wastewater control facilities such as manure pits, ponds, lagoons, or other devices.

3. The livestock operation is located near a stream or other aspects of the operation, such as improper disposal of dead animals, present potential water pollution problems.

4. Existing sale barns and collection centers provide capacity for more than 300 head and are utilized more than once a week.

5. The operation has livestock truck wash facilities, irrespective of size.

6. The operator(s) elects to come under the regulations.

It is important for swine producers to recognize that the 300 head is the total number of pigs on the farm, including those in gestation, farrowing, nursery, growing or finishing buildings, as well as the number that may be in outdoor lots. The total capacity is number of pigs plus other confined fed livestock and does not allow for adjustments based on animal weight, age, or type. The pig's weight or size will influence the size of holding pond or lagoon needed to handle the manure. Operations that have between 300 and

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2,500 head capacity are required to follow the regulations established for Kansas and directed through KDHE's Division of Environment. Operations with a capacity of 2,500 head or more are required to meet the regulation establish by the Environmental Protection Agency (EPA). KDHE administers the EPA program, and when the larger operations meet EPA requirements, they are issued a NPDES permit.

Production units with a capacity of 2,500 head or more are required to contain all runoff from dirt lots in a lagoon or holding pond. A lagoon is sized to breakdown the solids and nutrients in the manure prior to dispersing the liquids onto cropland or pasture. Lagoons are normally used for handling manure from buildings. In a holding pond, there is little or no breakdown of the solids prior to dispersing. The primary function of a holding pond is to contain the runoff from a dirt lot before the nutrients are dispersed on farmland.

Normally, no registration of the operation is required if the total capacity is less than 300 pigs, unless an operation has pollution potential or a neighboring complaint is issued against it. Smaller operators are not allowed to have pens adjoining or draining into a road ditch, creek, or other channels without adequate control, because of the pollution potential. Much of the pollution potential is minimized by frequent cleaning of the pens and proper disposal of manure onto cropland or pasture.

The regulations for operations between 300 and 2,499 head allow for either discharging or nondischarging systems depending on the size of operation and location of lots in relationship to waterways and levels and potential for pollution. A discharging system separates the solids from the liquids by using settling basins, terraces, grass filter strips, or sedimentation structures. After separation, the water is then discharged into a grassed waterway, pasture, or cropped field. A nondischarging system may include a method for separating the liquids and the solids but the liquids portion of the runoff is contained in an earthened structure. The pond is later pumped, and the water is dispersed onto cropland or pasture. Operations that have more than 2 acres of dirt lots or 750 pigs will probably be required to have a nondischarging type of waste control facility. A discharging system could be utilized for those with less than 2 acres of dirt lots or between 300 to 750 head capacity.

Figure 1 shows some of the options that are available for controlling the runoff from dirt lots. In each case there are certain restrictions that will apply and design specifications that have to be met. Some of the criteria are:

1. Dirt lots and runoff control facilities cannot be within 100 feet of the property line.

2. Water pollution control facilities must be able to handle the runoff generated by 25 yr/ 24 hr storm, which is equal to about 5 in. in western Kansas, 6 in. in central Kansas and 7 in. in eastern Kansas.

3. Lowest elevation of the feeding area or waste control facilities must a minimum of 10 ft above groundwater aquifers or seasonal perched tables.

4. The lots must be located a minimum of 100 ft from wells or reservoirs and 50 ft from rural water district lines.

5. Sedimentation structures are needed, with the type being dependent upon the drainage area.

6. If a holding pond or lagoon is used, then provisions must be made for pumping the water including both certain land requirements and pumping equipment.

Figures 1a, 1b, and 1c are examples of discharging systems. The runoff from the pens is uniformly dispersed onto cropland or pasture in Figure 1a. This type of system is normally used with operations less than 300 head or 1 acre in size. As the capacity increases, then the options shown in Figures 1b and 1c may be able to be used. In both of these designs, the sedimentation channel may be a terrace or channel and is sized to hold the runoff for 1 hr prior to discharging onto the land. The 1 hr retention time results in large sedimentation structures as the acreage of the lots increase. Figures 1d and 1e are examples of nondischarging systems. A nondischarging serpentine terrace system is shown in Figure 1d. The total capacity of the terrace channels has to be able to contain the 25 yr/24 hr storm runoff from the dirt lots and any additional drainage area. Figure 1e show a sedimentation channel with the runoff draining into a lagoon or holding pond. The sedimentation structure is optional for small lots but required if the drainage area is more than 15 acres. If waste water from a building is also draining into the pond, then a sedimentation structure should be considered.

These are only a few of the regulations. A complete copy can be obtained from the KDHE district or state offices. A holding pond or lagoon should be constructed with side slopes of 3 to 1, minimum berm width of 10 ft, and a minimum of 12 in of clay around the sides and in the bottom. The earthen structures cannot have a seepage rate greater than 1/4 in per 24 hr. Generally, the minimum storage period is 120 d with a minimum volume to handle 120 d of normal rainfall, 25 yr/24 hr storm, and manure production. The storage structures also must have a minimum freeboard depth of 2 ft. Additional details also are provided for pumping regulations, fencing, maintenance, and inspection.

Swine operators should not locate dirt lots near streams or running water or in areas like a ravine where cropland or pasture may drain through the pens. Any water draining from adjacent fields through a lot must be controlled using either a discharging or nondischarging pollution control system. Therefore, it is important to divert runoff from cropland or pasture around the dirt lots using terraces or channels. In some cases, it may be easier to relocate the pens rather than control the excess runoff. For new operations, dirt lots should be located on higher land rather than bottom land to minimize the drainage and potential pollution problems.

The livestock industry is giving greater attention to reducing its effect on the environment. As the demand grows for cleaner streamflows, smaller dirt feedlots will need to reduce and control the nutrient and sediment loading of the runoff leaving the feedlot vicinity.

Runoff potential of existing dirt lots will need to be evaluated. Costs of controlling the runoff must be weighed against new lot construction in an alternate location or new building construction. Future dirt lots will need to address current regulations and be designed for compliance with future and more stringent regulations.

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