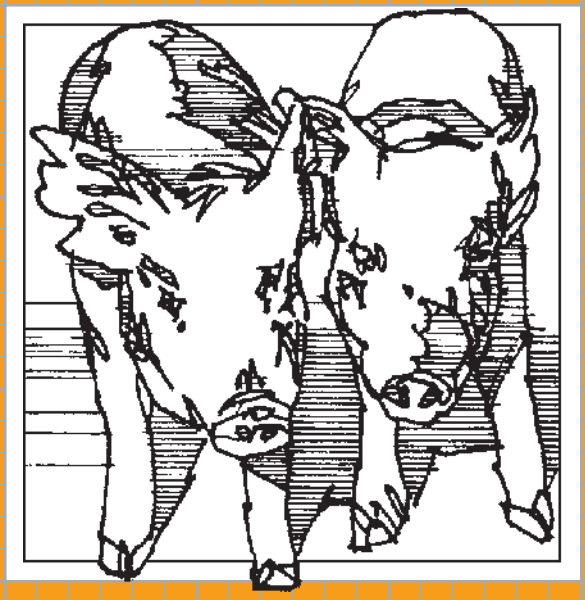

K-STATE
Kansas State University

SWINE DAY 1999

REPORT OF PROGRESS 841, KANSAS STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

FOREWORD

It is with great pleasure that we present to you the 1999 Swine Industry Day Report of Progress. This report contains updates and summaries of applied and basic research conducted at Kansas State University during the past year. We hope that the information will be of benefit, as we attempt to meet the needs of the Kansas swine industry.

Editors, 1999 Swine Day Report of Progress,

Bob Goodband Mike Tokach Steve Dritz

ABBREVIATIONS USED IN THIS REPORT

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

KSU VITAMIN AND TRACE MINERAL PREMIXES

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

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

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

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

NOTICE

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

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

CONTENTS

Growing-Finishing Pig 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.

Swine Day 1999

ON-FARM *SALMONELLA* TESTING: PERSPECTIVES OF PORK PRODUCERS

D. R. Mark[1], M. A. Boland[1], and J. A. Fox[1]

Summary

Pork producers in Kansas were surveyed to determine their attitudes regarding on-farm *Salmonella* testing and to provide estimates of the costs of collecting hide, fecal, or blood samples from live pigs. Veterinarians and Cooperative Extension Service personnel were cited most frequently as the most preferred groups for monitoring and verification. Results of the survey indicate that pork producers may be willing to conduct on-farm *Salmonella* testing, if they can recover the costs of sample collection. The sampling costs ranged from $1.76 to $4.72 per pig, depending on the method of sample collection.

(Key Words: On-Farm Testing, Preharvest HACCP, *Salmonella*.)

Introduction

Meat safety is best accomplished through an integrated systems approach that links on-farm production, slaughter, processing, and food preparation. Although the current system is coordinated fairly well, a failure at any level of the food chain, including production, could introduce risks and hazards. Because proposed production practices have uncertain costs (and benefits) and can be implemented in various ways, it is necessary to explore producers' attitudes towards implementing the production practices, as well as their costs.

In the USDA's study of the National Animal Health Monitoring System (NAHMS), nearly 30% of the swine operations in South Dakota, Nebraska, Kansas, Minnesota, Iowa, and Illinois tested positive for *Salmonella*. That study also found that 57% of operations that market more than 10,000 pigs annually were *Salmonella* positive, compared to less than 30% of operations marketing less than 2,500 pigs annually. The Food Safety and Inspection Service (FSIS) of the USDA reported that the average incidence of *Salmonella* on hog carcasses was 8.7%. Therefore, the prevalence of *Salmonella* on pigs as they leave the farm can be significant.

The objective of this research was to determine pork producers' attitudes toward an on-farm *Salmonella* testing program and the costs of development. Such a program could include producer decisions and practices that potentially could influence the food safety assurance process throughout the pork production and processing chain. The intent of an on-farm testing program is to decrease the risk of foodborne illnesses caused by *Salmonella* by reducing the incidence at the farm level. We should note that FSIS is not contemplating an on-farm testing program at the present time.

Procedures

Pork producers in Kansas were surveyed to determine their costs of collecting samples for *Salmonella* testing and their willingness to comply with an on-farm *Salmonella* testing program. Two-hundred and ninety members of the Kansas Pork Producers' Council comprised the survey population. Respon-

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dents were asked to provide information about their operation, attitude towards food safety, and how on-farm testing would affect their costs.

Demographic responses, such as the numbers of family and nonfamily employees, provided an indication of the overall size of the operation. Other questions requested that producers categorize their major pork production activities and the number of pigs involved in each process. This information described the size of the pork operation, which can influence the level of pathogens present on the production site. Because an on-farm testing program might be implemented voluntarily and because pork producers have some experience with voluntary quality programs through the Pork Quality Assurance (PQA) program, the survey respondents were asked to indicate the highest level of the PQA program that they had completed.

On-farm *Salmonella* reduction was described before producers were asked to estimate the costs of collecting samples to be tested for *Salmonella*. Three methods of sample collection were described: 1) restraining the pig and collecting a feces sample from the rectum, 2) restraining the pig and drawing a blood sample from the neck, and 3) wiping a sterile gauze pad or sponge against the pig's hide.

After the description of on-farm testing, pork producers were asked what they saw as the advantages and disadvantages of an on-farm testing program. Additionally, the respondents described their level of previous knowledge about *Salmonella* testing as well as their sources for new information on pathogens and food safety. The pork producers were asked to estimate the labor, management, facility, and handling costs of collecting the fecal, hide, or blood sample from five pigs in a pen (converted to a per pig basis by assuming that one pen contained 20 pigs). Therefore, their cost estimates did not include the cost of laboratory analysis of the samples for *Salmonella*.

Results and Discussion

Twenty-four % of the Kansas survey population returned the questionnaire. Over 95% of these respondents were males and, on average, two family members were employed in the pork operation. Seventy-eight % of the producers had completed PQA Level III certification. They reported annual average sales of 9,975 head.

An on-farm *Salmonella* testing program likely would require monitoring or verification of sampling and testing information. Figure 1 illustrates the producers' preference for groups to conduct verification and monitoring. Veterinarians and Cooperative Extension Service personnel were most preferred, whereas USDA personnel from either the Animal and Plant Health Inspection Service (APHIS) or the FSIS were less preferred to conduct the verification activities. Kansas producers also indicated relatively high levels of preference for private consultants and slaughter plant scientists.

The respondents' attitudes about food safety and their willingness to participate in on-farm tasks designed to increase food safety also were examined. Many producers believed that they can improve the safety of pork products on the farm. Figure 2 shows that 35% of Kansas producers believed that on-farm activities can "greatly increase" pork product safety, but over 60% of producers believed that they can only "marginally contribute". However, all respondents indicated that they would comply with requests from slaughter plants for changes in their production process. Approximately 60% of the Kansas producers indicated that they would expect a premium for compliance, whereas the remaining 40% were willing to comply without a premium.

Various types of on-farm testing can be used to detect the presence of *Salmonella*, and the costs are likely to differ for each based upon the pork producers' facilities and labor availability. Pork producers' decisions to participate in an on-farm *Salmonella*

testing program will not only be influenced by the costs of collecting samples from their swine herd, but also will be a function of their belief that the program, in fact, will reduce the prevalence of pathogens in the pork supply, their willingness to work with those administering the program, and their familiarity with foodborne pathogens.

Producers were asked to describe their knowledge of on-farm *Salmonella* testing. Most of the producers indicated that they had either never heard about on-farm *Salmonella* testing or knew very little about it. The majority of the Kansas producers indicated that most of their previous knowledge about on-farm pathogen testing was obtained from producer trade magazines and newspapers.

After reading the statement describing on-farm *Salmonella* testing, producers were asked to select from among six options the one they believed to be the single greatest benefit to on-farm *Salmonella* reduction. Over 50% of the Kansas producers identified safer pork products (Figure 3). However, nearly 10% of the Kansas producers reported no benefits to an on-farm *Salmonella* reduction program.

Over 40% of the producers identified live pig sampling costs to be the greatest disadvantage to an on-farm pathogen reduction program (Figure 4). Other producers identified feed sampling, animal identification, or record keeping as the greatest disadvantage, as well as other disadvantages such as inconvenience and time.

Testing a hide sample for *Salmonella* indicates if the pig has been exposed to feces containing *Salmonella*. Blood samples are tested to determine if the pig is producing an immune response to disease. A fecal sample test measures exposure to disease or the amount of *Salmonella* being shed by the pig. One of the main goals of the pre- and postharvest Hazard Analysis and Critical Control Points (HACCP) program is to reduce the amount of fecal contamination on pigs and carcasses so testing hide samples (rather than fecal or blood samples) for pathogenic *Salmonella* would most closely meet this goal.

The costs of collecting samples that producers were asked to estimate reflect increased labor, facilities, and management expenses, not the laboratory costs of analyzing the sample for *Salmonella*. Kansas producers estimated the costs for collecting hide, fecal, and blood samples to be $1.76 per pig, $2.14 per pig, and $4.72 per pig, respectively (Figure 5). The differences in the costs for the three methods of sampling were not statistically different, because of the small sample number and high variability in responses.

Current research is studying whether the implementation of on-farm *Salmonella* testing will significantly contribute to reducing *Salmonella* in the pork supply. Although the pork producers generally indicated a willingness to participate in on-farm *Salmonella* testing if they were compensated for doing so, few of the producers surveyed possessed a substantial knowledge of the process. Therefore, if on-farm *Salmonella* testing is to be adopted, more education is needed. Pork producers' preference for veterinarians and the Cooperative Extension Service personnel to conduct verification and monitoring of an on-farm *Salmonella* testing program suggests that these groups would be favorable choices to develop and conduct an education program.

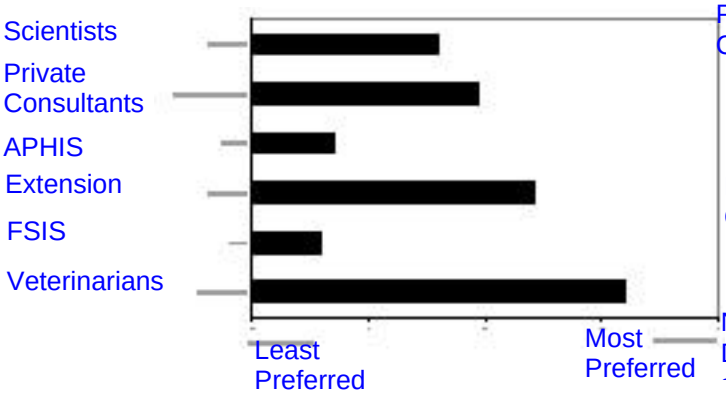

Figure 1. Preference for Verification and Monitoring.

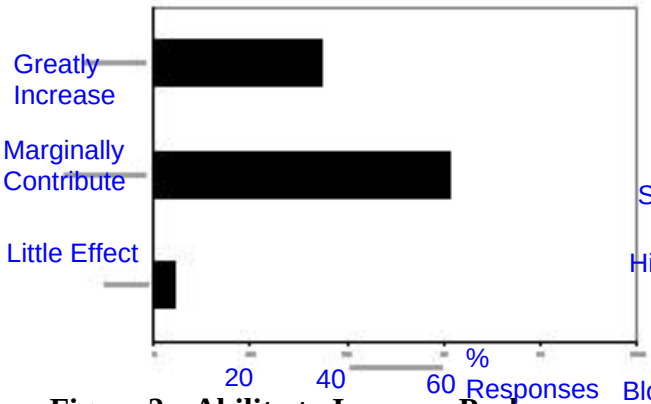

Figure 2. Ability to Improve Pork Product Safety on the Farm.

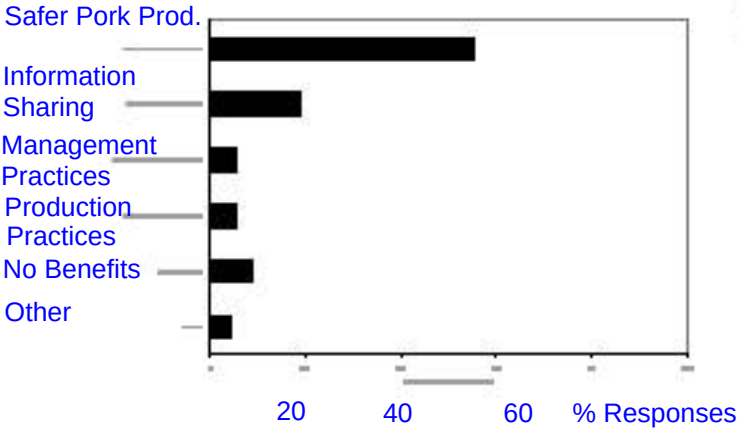

Figure 3. Greatest Advantage of On-Farm *Salmonella* Testing.

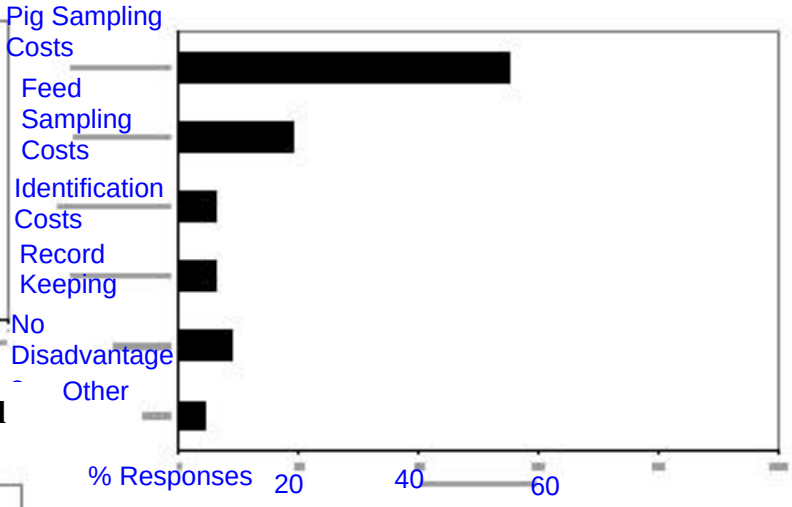

Figure 4. Greatest Disadvantage of On-Farm *Salmonella* Testing.

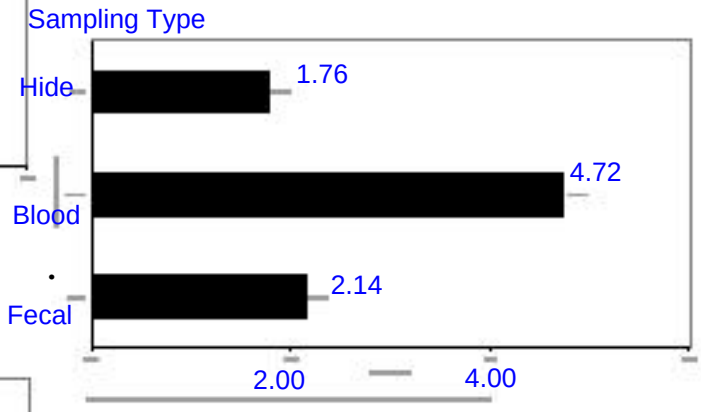

Figure 5. Live Pig Sampling Costs.

These cost estimates represent on-farm sampling costs and do not include laboratory costs.

MARKET HOG PRICE DISCOVERY

T. C. Schroeder[1] and J. Mintert[1]

Summary

Cash hog markets are declining in importance, and use of formula pricing of market hogs is increasing. Producers need more information to assist them in price discovery and formula price negotiations with pork packers. Lean hog futures and pork wholesale plus by-product values offer useful pricing information for producers. However, using these markets as sources of price information is not without challenges. This report highlights issues involved in hog market price discovery and examines the usefulness of lean hog futures and wholesale pork values in price discovery.

(Key Words: Price Discovery, Hog Prices.)

Introduction

Price discovery is an issue of considerable concern in the hog sector. Once common, local, hog-buying stations are rapidly being replaced with noncash methods of trade including contracts, marketing agreements, alliances, and formula pricing arrangements. As this occurs, cash hog market volume declines, cash price data become less readily available, and the representativeness of prices quoted from cash transactions become increasingly suspect. What are the consequences of cash hog markets disappearing? How will this impact price discovery for hog producers? This study examined these questions through analysis of alternative sources of price discovery information in slaughter hog markets.

Procedures

Weekly values for cash hogs, lean hog futures, wholesale pork, and pork by-products were collected over the 1991-July 1999 period. Analyses of the relationship between live hog prices and futures and wholesale prices were conducted to determine how viable these alternative markets are as price sources for producers involved in either cash hog price discovery or negotiating formulas for marketing agreements.

Results and Discussion

Market hog pricing methods have changed considerably over the past decade. Cash markets are disappearing, and formula pricing agreements are becoming common. Formula pricing refers to situations where the price for a particular transaction is based upon an external reference price, and a formula incorporating the external price is used to establish the transaction's price.

A survey of 12 leading pork packers in January 1999, conducted by the University of Missouri for the National Pork Producers Council (NPPC) determined that only 35.8% of hogs were purchased on a cash market basis. The remaining 64.2% of the hogs were procured using noncash methods, up from 56.6% in 1997.

The upward trend in contract and formula pricing is primarily a result of benefits accruing to both buyers and sellers from entering into marketing agreements. These benefits include reduced costs for both buyers and

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sellers compared to discovering prices for each transaction and reduced search costs by both parties.

However, formula pricing also presents several potential problems. Formula priced hogs do not contribute to price discovery. Currently, formula-price arrangement terms are not publicly collected or disclosed by the USDA. As a result, formula pricing agreements are not visible to the market.

Formula pricing is also problematic if the external price used as a base in the formula is thinly traded or subject to manipulation. For example, agreements using recent local cash market prices (e.g., the previous week's price) for a base are concerns if the base is either thinly traded or, during some days or weeks, not even traded at all.

Despite drawbacks to formula pricing, its economic incentives for individual producers and packers are strong. The market environment is increasingly encouraging more formula or long-term noncash pricing methods. Therefore, producers need to better equip themselves to operate in this new environment.

As cash market hog prices decline in importance, market participants are considering other sources for base prices and/or pricing information. A couple of the more viable alternatives are 1) lean hog futures prices and 2) wholesale boxed pork and by-product prices.

Lean hog futures prices are appealing as a potential base price because they typically have a large volume of trade, rapidly reflect new information, are viable sources of price expectations, provide readily available price quotes, and are closely monitored to avoid manipulation. In addition, futures price-based formulas significantly increase opportunities for price risk management. That is, futures-based formulas provide producers with certainty regarding basis levels, which greatly reduces the risk of hedging hogs.

However, several concerns are present regarding the use of futures markets as an external reference price. First, futures prices have a time-matching problem, in that they represent specific delivery or expiration dates that do not necessarily match the hog marketing date. Second, historical basis (cash price minus futures price) variability needs to be accounted for, if futures prices are to be used as a reference price source. Finally, if the cash lean hog market disappears, the lean hog futures market likely will face a similar demise.

To illustrate the relationship between a particular cash market and lean hog futures, the weekly Iowa – S. Minnesota (IA-SMN) hog price (converted to a carcass weight basis by dividing by 0.75) minus the nearby lean hog futures price (known as basis) is presented in Figure 1. The cash lean hog price varied from as much as $7.00/cwt carcass weight greater than the nearby lean hog futures price to as much as $15/cwt below the futures price.

A downward trend existed in the basis over the 1991-July 1999 time period. During the early 1990s, the cash price averaged roughly $2/cwt carcass weight below the lean hog futures price, albeit with a lot of weekly variability. However, since 1996, basis generally has weakened, and the IA-SMN market hog price has averaged $4.85/cwt carcass weight below the nearby futures price. This suggests that formulas based on lean hog futures would result in different and lower prices using recent years' basis values than futures-based formulas would have using basis values from earlier in the decade. Exactly why IA-SMN hog prices have declined relative to lean hog futures over time is not clear. However, one possibility is a change in the relative quality of cash hogs traded in the IA-SMN market. If higher quality hogs have moved away from cash market trade toward marketing agreements and lean percentage pricing arrangements, then the relative decline in cash market price may simply reflect this decline in quality.

Another possible external reference price to consider when establishing a base price is wholesale boxed pork cutout plus by-product

prices. Wholesale prices are appealing, because they potentially represent the market supply and demand for all meat products, whether they are going to retail, food service, or export markets. Although wholesale value-based prices are conceptually appealing, they offer several challenges from a practical perspective.

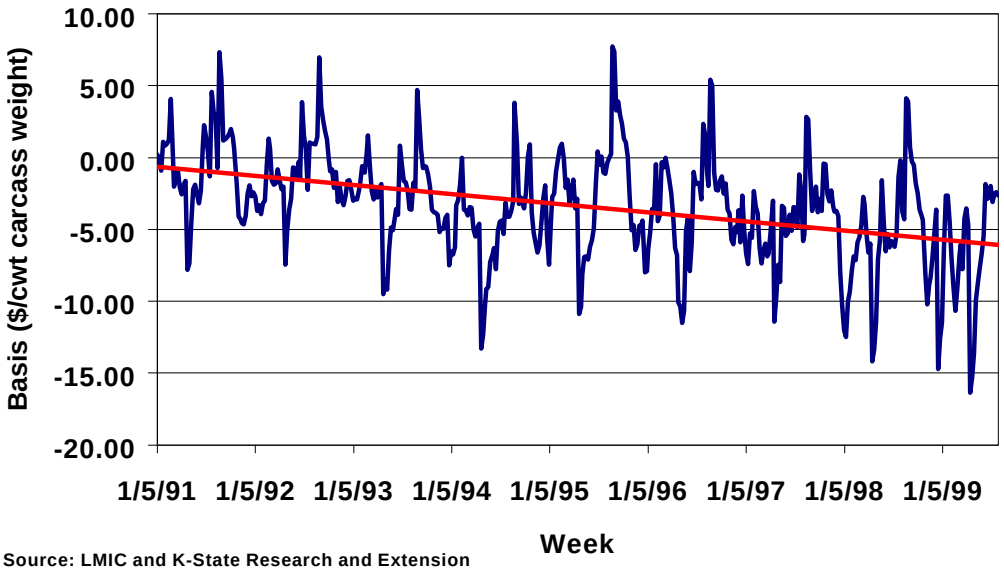
As slaughter and processing costs change, the relationship between wholesale and farm level prices also changes. Therefore, the relationship between unprocessed raw farm product and processed fabricated meat cuts varies. This was especially true in fall 1998, when demand for slaughter and fabrication services peaked and the spread between wholesale and live or carcass weight hog prices set a record.

The ratio of the weekly live hog price to the pork cutout plus by-product value has declined over the 1991 to July 1999 period (Figure 2). During the early and mid 1990s, the reported IA-SM live hog value per head was typically 85% to 97% of the wholesale and by-product value. In 1998 and early 1999, this ratio was generally less than 80% and dropped to approximately 35% in December 1998. It's premature to conclude that live values have shifted permanently to a lower level relative to wholesale values, because they recently have rebounded back to approximately 85% of wholesale values.

However, the variability in the ratio suggests that it will be difficult for pork producers to base prices purely off of wholesale values without allowing for variation in processing margins associated with changes in processor costs or industry processing-capacity utilization rates. This week-to-week variability in farm to wholesale pork price spreads is not necessarily a deterrent to wholesale-based farm-level pricing, if one is marketing hogs regularly so the weekly "peaks" in the spread are offset by the "troughs". However, using a particular week's wholesale value in a base price relationship may be more problematic for someone who markets hogs less frequently.

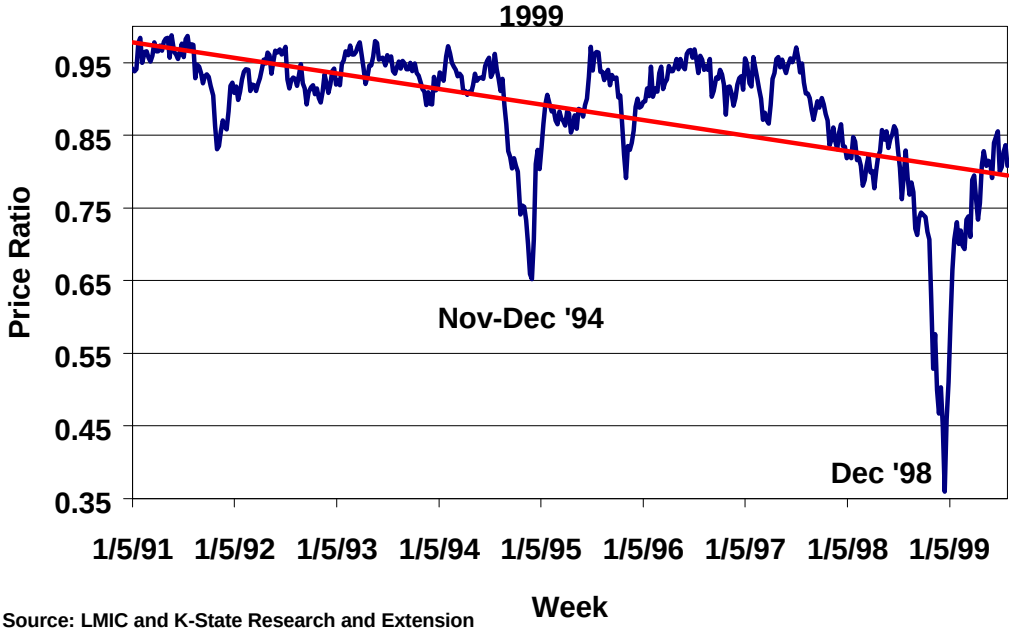
As cash hog market volumes continue to decline, hog producers will increasingly need to rely on other markets for pricing information and for establishing formula base prices. Two alternative markets to consider are the lean hog futures and the wholesale pork markets. However, use of either of these markets also presents challenges, because their relationships with live hog prices are not stable. Producers wishing to establish base prices off of either of these markets are encouraged to do additional analyses and design formulas that will help assure that the prices they are receiving are reflective of market conditions.

Figure 1. Weekly Iowa - S. Minn. Barrow and Gilt Basis (Cash Price minus Nearby Lean Pork Futures Price), 1991 - July 1999



Source: LMIC and K-State Research and Extension

Figure 2. Ratio of Weekly Iowa-S. Minn. Barrow and Gilt Value to Pork Cutout Plus Byproduct Value ($/head), 1991 - July 1999



Source: LMIC and K-State Research and Extension

MANURE COMPOSITION FROM KANSAS SWINE LAGOONS

J. D. DeRouchey, G. L. Keeler[1], R. D. Goodband, J. L. Nelssen, M. D. Tokach[2], and S. S. Dritz[3]

Summary

Analysis of 41 manure samples from Kansas swine lagoons revealed that nutrient concentrations were higher than previously reported values from the Nebraska Cooperative Extension Service and the Midwest Planning Service. In addition, high standard deviations indicated that considerable variation exists in composition of waste in swine lagoons. Although means from some lagoons were lower, most producers had manure that analyzed higher than previously published values from other sources. These data reveal the importance of individual analysis of lagoons for proper application to cropland to maximize yield and environmental stewardship. Additional research needs to be completed to provide a more detailed understanding of nutrient concentrations from manure samples in Kansas.

(Key Words: Swine Lagoons, Manure, Environment.)

Introduction

Manure application to cropland compared to direct application of inorganic fertilizer is an important economic consideration for producers. Soil characteristics of structure, tilth, and water holding capacity are improved when manure is applied. Although applying swine manure to cropland is a common practice, active participation in environmental stewardship must be a top priority. Currently, no database for manure nutrient concentrations exists from Kansas swine lagoons, therefore values from other sources are used to compare Kansas concentrations. Many potential problems with using these values exist, because these concentrations possibly were generated in other geographic locations with no uniform sampling technique and from samples collected many years ago. Furthermore, changes in management practices (i.e., phase-feeding, decreased particle size) and dietary factors such as feeding milo and wheat, which have greater available P than corn, also may affect the composition of Kansas swine lagoons. Therefore, a need exists for a database from samples of manure to determine the level of nutrients and minerals in Kansas swine lagoons. The objective of this survey was to determine mean concentrations of major and minor nutrients in swine lagoon samples from analysis filed in nutrient management plans at the Kansas Department of Agriculture in accordance with of HB 2950.

Procedures

Analyses of swine manure from 41 Kansas swine lagoons were obtained from the Kansas Department of Agriculture. Manure samples were obtained in 1999 from farrowing to finishing, sow, nursery, weaning to finishing, and finishing operations. The manure samples were collected by the individual operations for chemical analysis. Therefore, the sampling technique, time of year, type of lagoon, sample handling prior to analysis, and the laboratory used were not

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

controlled among operations participating in this survey. Average concentrations of specific nutrients and minerals from all lagoons were summarized to obtain a database for mean values. In addition, the standard deviation (SD) of the mean for each nutrient and mineral was calculated. One SD indicates that 68% of the samples are ± 1 standard deviation from the mean. A range of two SDs would include 95% of the samples.

Results and Discussion

The nitrogen contents of the manure from Kansas lagoons (Table 1) were higher than previously reported values from sources located in other states (Table 2). For ammonium nitrogen (NH_4-N), which is available to plants during the growing season, Kansas lagoon concentrations were 709 ppm compared to 375 ppm from the Nebraska Cooperative Extension Service. The SD for NH_4-N was 398 ppm. This indicates that 68% of the samples have a range of 310 to 1,107 ppm concentration of NH_4-N. The amount of organic nitrogen (OrgN), which is nitrogen that is slowly released from the manure into the soil, was 190 ppm with an SD of 209 ppm. In addition, the amount of nitrogen in the nitrate form was less than 1 ppm. The total nitrogen in the manure, which is the sum of ammonium-nitrogen, organic-nitrogen, and nitrate-nitrogen, was 899 ppm with an SD of 584 ppm. This compares to the values from Nebraska and the Midwest Planning Service of 500 and 625 ppm, respectively.

For phosphorous concentration, the level of phosphate (P_2O_5) was 371 ppm. This mean is similar to the reported value of 375 ppm from the Midwest Planning Service. But, with an SD of 549 ppm, many of the manure samples would have concentrations under the Midwest Planning Service values. Elemental phosphorus, which is calculated by multiplying P_2O_5 by .44, had a mean of 163 ppm.

Potash (K_2O) levels were double the previous reported concentrations: 1,043 ppm compared to 500 ppm for both Nebraska and the Midwest Planning Service. For potassium, which is calculated by multiplying K_2O by .83, Kansas swine lagoons had a mean of 847 ppm. However, the SDs of 617 ppm for K_2O and 519 ppm for potassium indicated a high degree of variability among samples in this survey.

Our summary of the lagoons in Kansas also includes additional nutrients and mineral concentrations. Currently, we are not aware of any other sources with which to compare these major and minor nutrients concentrations. However, high SDs for the majority of these nutrients and minerals indicated a high variation between samples.

In order to determine how different types of operations compare in manure concentrations, as well as to increase the current knowledge of swine manure content, we are planning a study to further analyze nutrients in swine waste. This will allow determination of manure content from different phases of production with a uniform sampling technique to reduce possible variation between samples.

Application of manure to farmland is an environmentally and economically feasible practice for swine producers. Results for 1999 manure concentrations from Kansas swine lagoons indicate the importance of individual manure analyses of all manure storage facilities. In addition to management and dietary factors that could contribute to the variation in manure composition, variation between laboratories may exist. The Minnesota Department of Agriculture has established a certification process for laboratories conducting manure analysis. Producers are recommended to have certified labs analyze their samples to ensure accuracy of manure composition. This practice will allow proper amounts of manure to be supplied to cropland for optimal plant growth, as well as increase environmental stewardship by swine producers.

Table 1. 1999 Nutrient and Mineral Concentrations of Kansas Swine Lagoons[a]

Item, ppm	Mean	SD	Minimum	Maximum
Nitrogen				
Total nitrogen, N	899	584	76	2,361
Organic-nitrogen, OrgN	190	209	12	1,107
Ammonium-nitrogen, NH_4-N	709	398	64	1,702
Nitrate-nitrogen, NO_3-N	< 1	0.0	< 1	< 1
Major Nutrients				
Phosphorus, P	163	241	13	1,209
Phosphate, P_2O_5	371	549	30	2,748
Potassium, K	847	519	164	2,069
Potash, K_2O	1,043	617	190	2,400
Sulfur, S	44	43	10	200
Calcium, Ca	154	85	40	345
Magnesium, Mg	60	82	6	226
Magnesium oxide, MgO	76	81	10	330
Minor Nutrients				
Zinc, Zn	6.2	8.9	1	32
Iron, Fe	19.0	25.4	2	67
Manganese, Mn	2.0	2.9	0	9
Copper, Cu	1.6	2.3	0	12
Boron, B	1.2	.8	0	3
Other Constituents				
Sodium, Na	243	112	90	400
Chloride, Cl	390	248	73	1,149
Carbonate, CO_3	< 1	0.0	< 1	< 1
Bicarbonate, HCO_3	3,943	1,609	714	5,868
pH	8.0	.6	6.1	8.8

[a]Values represent the means of 41 swine lagoon samples. These analyses were sent into the Kansas Department of Agricultural as part of compliance with KHB 2950.

Table 2. Nutrient Concentrations of Swine Lagoon Manure

Item, ppm[a]	Nebraska[b]	Midwest Planning Service[c]
Nitrogen		
Total nitrogen, N	500	625
Ammonia-nitrogen, NH_4-N	375	NR[d]
Major Nutrients		
Phosphate, P_2O_5	250	375
Phosphorus, P[e]	110	165
Potash, K_2O	500	500
Potassium, K[f]	415	415

[a]Converted from lb/1,000 gal.
[b]Nebraska Cooperative Extension Service, EC 89-117, Lincoln, NE.
[c]1993.
[d]Not reported.
[e]Converted by multiplying P_2O_5 by .44.
[f]Converted by multiplying K_2O by .83.

A NEW TREATMENT FOR NEONATAL SCOURS[1]

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Summary

Scours account for significant losses to the US swine industry every year. A common treatment for scours is the administration of broad-spectrum antibiotics, a practice with increasing unpopularity in the eyes of consumers. Currently, no treatment is available to reduce or eliminate the fluid losses associated with scours that is both inexpensive and easy to use. In the present study, a variety of prospective drugs were used to determine if a single compound might inhibit the effects of bacterial toxins in a laboratory setting. The results indicate that a new class of drugs, which we call DASUs, likely will prove useful for the treatment of watery diarrhea. Additional studies are underway to validate this conclusion.

(Key Words: Scours, New Treatments.)

Introduction

Scours (watery diarrhea) accounts for at least $70 million in losses to the swine industry in the United States annually. Although several general mechanisms can produce diarrhea, the most frequently encountered causes can be grouped into two categories: 1) those that stimulate intestinal cells to secrete electrolytes and water (e.g., enterotoxins of *E. coli* or *V. cholera*) and 2) pathogens that destroy cells lining the intestine and result in 'bloody scours' or dysentery. Sickness from electrolyte and fluid losses is greatest in newborn and newly weaned animals, and mortality approaches 100% when it is untreated. Scours accounts for greater than 15% of all deaths in nursery age pigs in the US swine herd, with only respiratory infections accounting for greater mortality. Other economic losses occur from reduced piglet weight gain, increased susceptibility to opportunistic pathogens, and the additional labor and materials required to treat affected litters.

Once an outbreak of scours occurs, a common method of treatment includes the administration of antibiotics without regard to the causative agent. Broad spectrum antibiotics will not reduce or reverse most diarrheas, although they may be appropriate to preclude opportunistic infections. Furthermore, there is mounting public pressure to reduce or eliminate all uses of antibiotics in livestock production. Nonantibiotic drugs that limit the impact of scours are few and require labor-intensive application. A variety of management techniques can be used to reduce the likelihood of scours, but outbreaks will continue to occur, at least sporadically. Thus, an ongoing need exists to develop nonantibiotic interventions that will limit or reverse fluid loss, are inexpensive, and require minimal labor for administration.

Intestinal cells use distinct proteins as machinery to move electrolytes and water from the animal's body into the intestine. We currently do not know if the same cellu-

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lar proteins are used by all pathogens to result in scours or if each organism takes advantage of different cellular proteins. Thus, it is unclear if any single protein is required for scours to occur and could be 'targeted' for drug development to reduce the impact of scours. Numerous research drugs are available to assist in identifying which proteins are used by a given pathogens. Additionally, we have identified a drug (DASU-02) that may prove useful in the treatment of scours.

In the present study, we focused on bacteria and toxins that stimulate the cells lining the intestine to secrete electrolytes and water and attempted to answer two questions: 1) Do toxins that come from different strains of organisms take advantage of the same cellular proteins? and 2) Can we identify a long-acting nonantibiotic drug that will reduce the fluid loss during scours? We should emphasize that this is a study designed to identify drugs that have the potential to be developed for commercial use; such compounds are not yet available.

Procedures

All procedures were completed in the laboratory using tissues obtained from 7- to 11-day-old pigs recently slaughtered in accordance with protocols approved by the Institutional Animal Care and Use Committee. Because toxins are known to affect the intestine, we removed sections of the large intestine and kept them functioning in tissue chambers for up to 8 hours. Small electrical currents were used to measure the amount of electrolytes being secreted by each piece of tissue. In each experiment, a tissue was mounted in a chamber and exposed to a bacterial toxin (either the heat-labile or the heat-stable toxin of *E. coli* or cholera toxin). The toxins stimulated electrolyte secretion by the intestine. A variety of drugs that are known to block certain cellular proteins were then added to determine which might inhibit the effects of the bacterial toxins.

Results and Discussion

Figure 1A shows the results from a single experiment in which *E. coli* labile toxin (LT) was used to stimulate the intestine. After about 90 minutes of exposure to LT, the current slowly rose, which indicates that the toxin was causing the tissue to secrete electrolytes. After an additional 90 minutes, the tissue was exposed to $CdCl_2$, a compound that blocks some proteins that cause electrolyte secretion in tissues such as the stomach. It had no effect, which indicates that these proteins are not responsible for secretion in the pig large intestine. DNDS is a compound that blocks proteins that cause secretion in other tissues such as the trachea. Again, no effect occurred, which indicates that these proteins are not responsible for LT-stimulated secretion in the pig intestine. Finally, the tissue was exposed to DASU-02, a compound that we previously discovered to block electrolyte secretion in cultured human intestinal cells. As the curve in Figure 1A shows, DASU-02 immediately and completely reversed the effects of LT on the intestine. Figure 1B shows the summarized results from 12 similar experiments. In each case, $CdCl_2$ and DNDS had no effect on LT-stimulated secretion regardless of the order in which they were applied, but DASU-02 completely reversed the effects of LT on intestinal electrolyte secretion.

Results presented in Figure 2 are similar to those presented in Figure 1, with the exception that *E. coli* stable toxin A (STa) was used as the stimulant of electrolyte secretion. STa behaves very differently from LT in that the stimulation of secretion is immediate, but not as great in magnitude. Nonetheless, results again show that neither $CdCl_2$ nor DNDS had any effect on STa-stimulated intestinal secretion. DASU-02 once again caused an immediate reversal of STa-stimulated electrolyte secretion. Results from a total of nine experiments are summarized in Figure 2B.

Results presented in Figure 3 demonstrate that inhibition by DASU-02 is extremely structure-specific. Again, E. *coli* labile toxin stimulated electrolyte secretion over a 3-hour period. Then DASU-H was applied to the tissue, but without effect even at the highest concentration employed. Subsequently, DASU-02 was applied to the tissue and produced the expected result of complete inhibition. We should note that DASU-H and DASU-02 are greater than 85% identical in structure; only one component of the molecule differs. Thus, the results presented in Figure 3 demonstrate that DASU-02 is interacting with a particular cellular target and that it is not merely causing a nonselective or toxic effect on the intestine. Furthermore, our data indicate that a significant inhibition can occur with a lofold lower concentration of DASU-02 (not shown).

Taken together, these data strongly suggest that pathogens that cause watery diarrhea take advantage of a single cellular protein that is inhibited by DASU-02, but is not affected by a closely related chemical, DASU-H, or by $CdCl_2$ or DNDS. Thus, the first criteria for drug development have been met, in that we have shown chemical selectivity for this target and reversal of toxin-induced effects in the pig intestine. Results that were not included in this report indicate that DASU-02 is selective for the protein that causes secretion in the intestine and, thus, will be selective for this tissue. Studies currently are underway to determine if the drug will be long-acting in pigs and if it will be effective in a clinical setting.

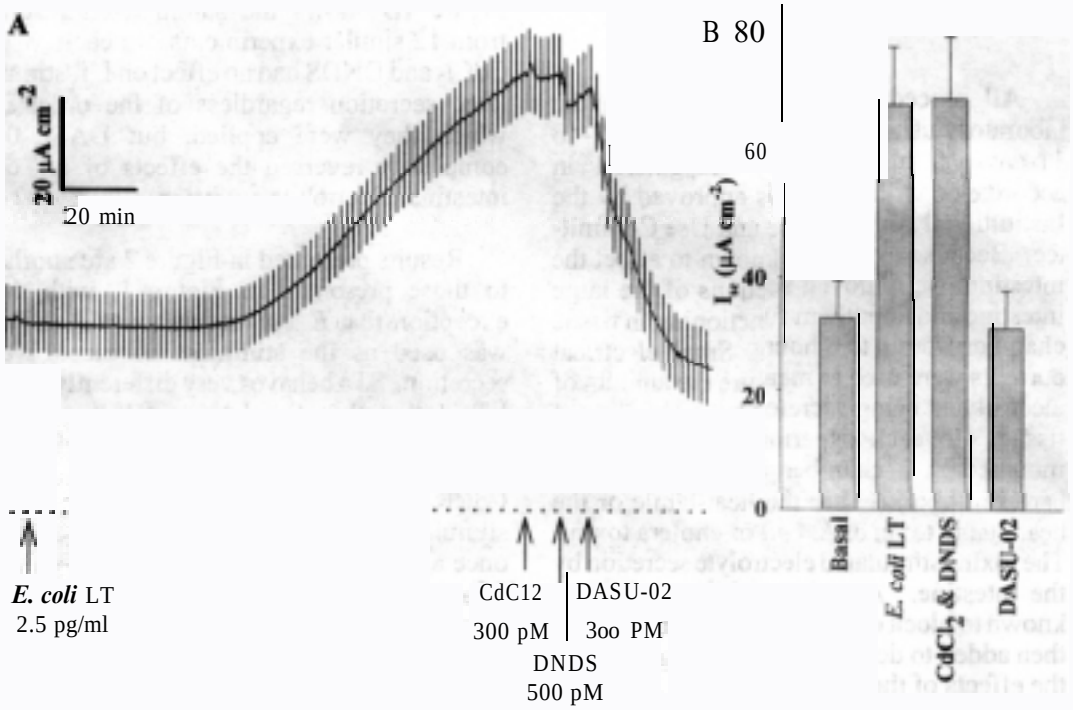

Figure 1. Inhibition of E. *coli* Labile Toxin-Stimulated Electrolyte Secretion.

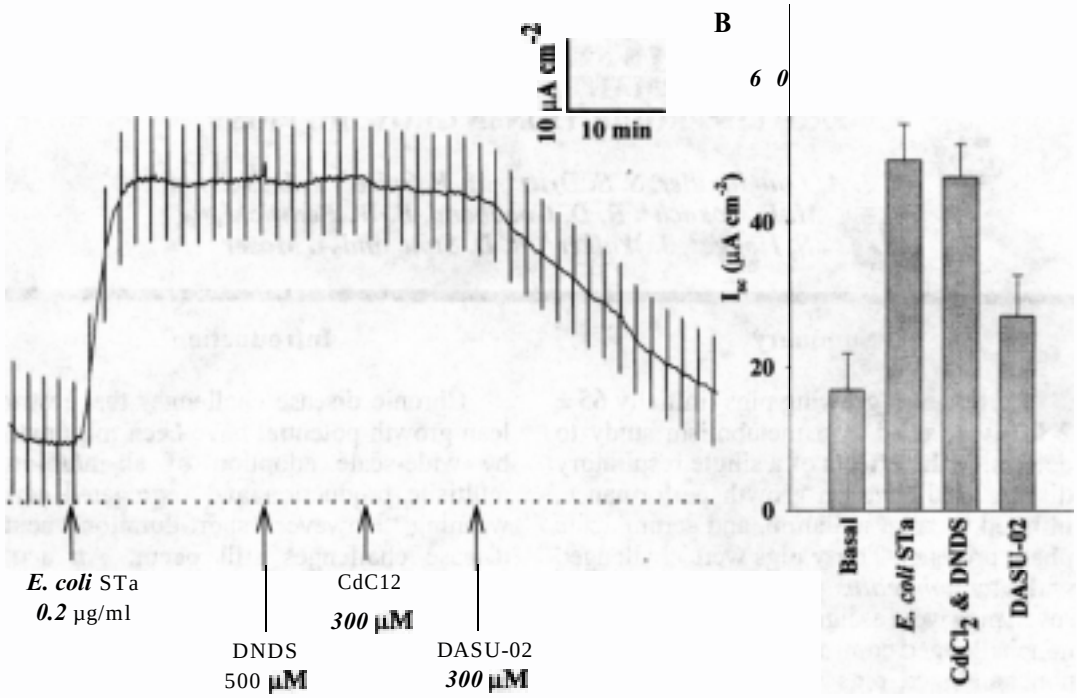

Figure 2. Inhibition of E. coli Stable Toxin-Stimulated Electrolyte Secretion.

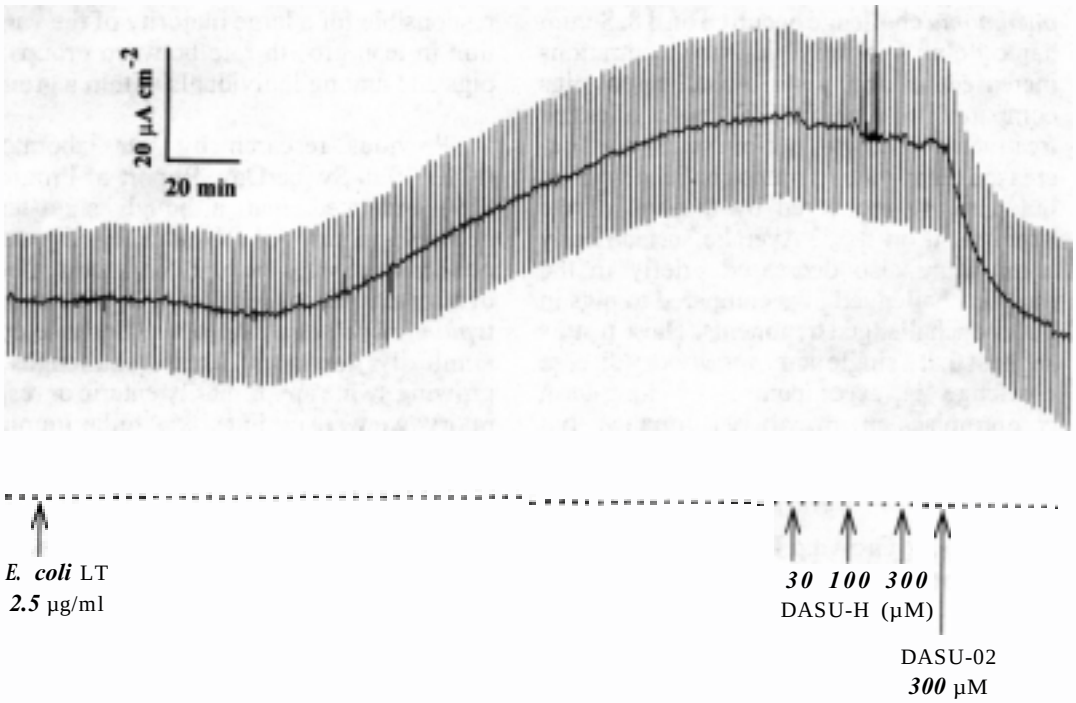

Figure 3. Inhibition of E. coli Labile Toxin-Stimulated Electrolyte Secretion by 02 but Not by a Closely Related Compound, DASU-H.

EFFECTS OF AN ACUTE RESPIRATORY DISEASE CHALLENGE ON GROWTH, THERMAL RADIATION, AND ACUTE PHASE PROTEIN PRODUCTION IN GROWING PIGS[1]

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Summary

Forty-seven growing pigs (initially 65 ± 2 lb) were used in a metabolism study to determine the effects of a single respiratory disease challenge on growth performance, infrared thermal radiation, and serum acute phase proteins. Thirty pigs were challenged with *Actinobacillus pleuropneumonia,* and seven pigs were assigned to an ad libitum-fed nonchallenged control group. Ten additional nonchallenged pigs were pair-fed the feed intake of an *A. pleuropneumonia*-challenged counterpart. There were five 4 d collection periods (d 4 to 7, d 8 to 11, d 12 to 15, d 16 to 19, and d 22 to 25), and the A. *pleuropneumonia* challenge occurred on d 8. Serum haptoglobin and amyloid A concentrations increased in the disease-challenged pigs compared to pigs in both nonchallenged treatments. Growth performance was decreased during the immune challenge period but partially recovered by the end of the experiment on d 25. Average surface body temperature also decreased briefly in the disease-challenged pigs compared to pigs in both nonchallenged treatments. These results suggest that a single acute respiratory disease challenge is accompanied by long-term compromises in growth performance, but performance partially recovers as the pigs overcome the immunological challenge.

(Key Words: Growing Pigs, Growth, Acute Phase Proteins, Respiratory Disease.)

Introduction

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

Previous research by our laboratory (KSU 1998 Swine Day, Report of Progress 819) indicated that although short-term decreases in nitrogen (N) balance and growth performance were evident, long-term effects of an enteric disease challenge by *Salmonella typhimurium* were negligible. Because economically important disease challenges in growing swine are primarily enteric or respiratory, we were curious if a similar immune response pattern would occur when *Actinobacillus pleuropneumonia* was used as the respiratory disease agent. Furthermore, we wanted to test infrared thermography (IRT) for detecting differences in surface body

[1]The authors thank Dr. Thomas McDonald and Annika Weber, University of Nebraska and Tri Delta Ltd, Republic of Ireland for technical assistance and product support of the serum amyloid A analysis.

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temperature associated with immunological stress. This new method to assess general health may have potential as a diagnostic tool.

Therefore, our objective was to characterize the effects of an acute respiratory disease challenge on growth performance, surface temperature profile, and hepatic acute phase proteins.

Procedures

The experimental protocol used in this study was approved by the KSU Institutional Animal Care and Use Committee. Forty-seven nonlittermate high-health barrows (PIC C22 × L326; initially 65 ± 2 lb) were obtained from the university swine herd after serological testing to ensure *A. pleuropneumonia (App)* negative status. Pigs were blocked by weight and time and allotted to one of three experimental treatments. Pigs were selected in groups of 12 from the same farrowing group and assigned randomly to either the *App* challenge or control group. Within the control group, pigs were assigned randomly to receive ad libitum feed intake or to be pair-fed the previous day's feed intake of an assigned *App*-challenged pig. Once the pair-fed control pigs were allotted to an *App* challenge pig, they were not reassigned at the start of each period but were fed the feed intake of the same *App*-challenged pig.

Because of a 23% mortality rate in the *App*-challenged pigs, adjustments were made to maintain the control pair-fed pigs on test. If the challenge pig of a pair died, the pair-fed control was reassigned to a new challenge pig. Every effort was made to reassign the control with a challenge pig with weight and prior feed intake pattern similar to those of the deceased challenge pig. The pair feeding was performed to elicit the responses independent of feed intake. Water was supplied at a 3.5:1 ratio with feed on a wt:wt basis, consistent with previously published research (i.e., 2.5 lb water per pound of dry feed). All pigs were fed and watered twice daily at 7:30 a.m. and 7:30 p.m. Orts were collected daily. Because of the expected greater variation in performance of the *App* group, 30 pigs were assigned to that group, 10 pigs to the control pair-fed group, and 7 to the control ad libitum-fed group. All pigs were fed a common corn-soybean meal diet formulated to 1.15 % total lysine, without synthetic amino acids, added fat, or antibiotics (Table 1). Following a 3 d adjustment period, there were five 4 d collection periods (d 4 to 7, d 8 to 11, d 12 to 15, d 16 to 19, and d 22 to 25), and the *App* challenge occurred on d 8. These periods correlated to prechallenge, challenge, recovery (8 d), and postchallenge. The latter period was selected to be at least 14 d postchallenge. Pigs assigned to the *App* challenge treatment were inoculated intranasally with doses ranging from 5×10^7 to 1×10^8 cfu *A. pleuropneumonia* in 3 mL culture medium; the control pigs were given 3 mL sterile culture medium intranasally.

Table 1. Diet Composition

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

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

All pigs were housed in two similar environmentally controlled rooms based upon health status and were kept in adjustable individual stainless steel metabolism cages (5 ft × 2 ft).

Serum was harvested from blood samples drawn via jugular venipuncture on d 5, 9, 13, 17, and 23 at least 2 h after feeding and analyzed for ∝-1 acid glycoprotein (AGP), amyloid A, and serum haptogolobin concentrations.

All pigs were euthanized humanely on d 27 by intravenous sodium pentobarbitol administration. After the pigs were

euthanized, they were transported to the KSU veterinary medicine diagnostic laboratory for disposal.

Average surface body temperature was collected on d 7, 8, 9, 12, 16, 20, 22, and 25, to determine the effects of feeding regimen or disease challenge. Infrared thermographs of the left side of each pig's body were taken using a stationary short wavelength (3-5 μm), 256 × 256 focal plane array, 16°FOV lens thermal imaging camera, at a distance of approximately 6 feet from the left side of each pig. Captured images were collected by a certified technician onto a computer disk for analysis of the pig's average surface body temperature.

All data were analyzed as a randomized incomplete block design using a mixed model procedure with repeated measures. Pigs were blocked by initial weight and time with individual pig as the experimental unit. Periodic samples by pig were used for the repeated measures. Average surface body temperature was adjusted to a common temperature of 21°C. Linear and quadratic polynomial contrasts were used to determine the effects of *App* challenge over time on all response criteria. Within the challenge treatment, the challenge pigs that were actually paired with a control pig (pair-fed) were separated to compare results of disease challenge directly between pigs of similar feed intake levels.

Results and Discussion

A disease status effect and a linear time effect (P<.05) were observed for ADG (Table 2). The disease status effect was a result of decreased ADG from d 8 to 11 of the *App*-challenged pigs (P<.01) and the pair-fed control pigs (P<.04) versus the ad libitum-fed control pigs. Decreased ADG also was observed from d 12 to 15 for the pair-fed control pigs versus *App*-challenged pigs (P<.06) or ad libitum-fed control pigs (P<.04). The decreased ADG associated with disease challenge and pair feeding carried through for the d 8 to 25 overall post-challenge period. Average daily gain was lower for both *App* (P<.02) and the pair-fed controls (P<.03) compared to ad libitum-fed controls.

A tendency for a disease status by time interaction was observed for ADFI (P<.06), primarily as a result of decreases in d 8 to 11, d 12 to 15, and d 16 to 19 ADFI for both the *App* pigs and the pair-fed control pigs versus the ad libitum-fed control pigs (P<.05). In addition, ADFI remained lower for the pair-fed control pigs versus the ad libitum-fed control pigs from d 22 to 25 (P< .05). These decreases in ADFI resulted in lower overall postchallenge ADFI for *App* pigs and pair-fed control pigs versus ad libitum-fed control pigs (P<.01). Average daily feed intake tended to be lower for the pair-fed pigs compared only to their pair challenge counterparts on d 16 to 19 (P<.09) and was different on d 22 to 25 (P<.02). These differences resulted in a tendency for decreased ADFI for the pair-fed controls versus the *App* pigs from d 8 to 25 (P<.09). This discrepancy in d 8 to 25 ADFI is a result of the pair-fed controls being fed the net feed intake of their challenged counterpart 24 h later. Feeding the net feed intake 24 h later leads to lower feed intake because of the time lag between periods and feed wastage of the pair-fed pigs. Feed efficiency (G/F) also appeared worse for pair-fed controls compared to *App*-challenged pigs and ad libitum-fed control pigs from d 12 to 15 (P<.05). Feed efficiency was not different between pair-fed control pigs and their challenged counterparts during any period (P<.54). This indicates that the decrease in feed efficiency was primarily due to severe reductions in feed intake. In general, large differences in growth performance were observed during the d 8 to 11 challenge period and the d 12 to 15 recovery period. Furthermore, the differences associated with an acute respiratory challenge were not completely overcome by d 25, leading to differences in growth for the overall postchallenge period. This indicates that these pigs did not completely recover by the end of the experiment, so the effects of the respiratory challenge on growth performance are more long term.

A disease status by time interaction was observed for serum haptoglobin and amyloid

A concentrations (P<.0l; Table 3). Serum haptoglobin levels were elevated for the *App*-challenged pigs versus the ad libitum-fed control pigs and the pair challenge controls on d 9, d 13, and d 17 (P<.01), and were highest on d 13. Serum amyloid A concentrations exhibited a pattern similar to that of serum haptoglobin levels, but changed more rapidly. Serum amyloid A levels of the *App*-challenged pigs were elevated above those of both nonchallenged control treatments on d 9 (P<.001) and d 13 (P<.004), with the peak on d 9. Alpha- I acid glycoprotein levels did not exhibit a similar pattern and did not differ among any treatments during any time period. The lack of an acute phase response in the control pigs indicates that our biosecurity measures were adequate, and the control pigs did not have an active immune response. The differential responses of the acute phase proteins suggest two things. First, acute phase proteins may be more disease specific than originally thought. Previous research by our laboratory using *S. typhimurium* as the disease agent resulted in elevated levels of both haptoglobin and AGP, but serum amyloid A was not measured. Secondly, consistent with earlier published research, the kinetics of individual acute phase proteins is not similar, but each appears to have its own reaction time course during the host immune response.

A disease status by time interaction was observed for average surface body temperature (P<.02; Table 4). The interaction resulted from *App*-challenged pigs having decreased body temperature on the day of the challenge compared to that for both control treatments (P<.005). The interaction was a further result of decreased body temperature of the pair-fed control pigs when compared to the *App*-challenged pigs 12 d after challenge (P<.04). These differences in body temperature likely were due to decreased metabolic heat production from reductions in previous ADFI. However, the lack of consistent changes in surface body temperature suggests that the pig is an efficient regulator of internal body heat production, and that when heat production is altered, heat loss also is moderated to maintain temperature.

A major portion of the differences in growth performance between *App*-challenged pigs and ad libitum-fed control pigs was due to feed intake differences. The differences between the pair-fed controls and ad libitum-fed controls indicate the differences in performance from feed intake. Differences in growth for the *App*-challenged pigs compared to the pair-fed controls were not as apparent and indicate that an *App* challenge reduces growth performance mainly through reductions in ADFI. We hypothesize that the reductions in ADFI are associated directly with the decreased oxygen exchange capacity of the *App*-challenged pigs' lungs, and that the decreased oxygen exchange capacity decreases the internal capacity to utilize available metabolic fuels. Thus, the pig adjusts its feed intake to meet its capacity for aerobic cellular energy utilization.

The results of this experiment are consistent with previous studies indicating that growth performance is affected negatively by immune activation. It also indicates that the intranasal dose of 5×10^7 to 1×10^8 cfu of *A. pleuropneumonia* is sufficient to produce an acute immune response.

Previously, we evaluated the effects of an acute *S. typhimurium* challenge on pig performance and found few or no long-term effects. This experiment suggests that an acute respiratory challenge of *A. pleuropneumonia* is longer acting, and that pig growth performance does not recover as quickly, leading to greater economic losses. These responses are more in line with long-term effects observed in the commercial swine industry. In contrast to commercial conditions, though, the lack of additional environmental stresses, such as social interaction with penmates, reinfection from other pigs, and competition for feed and water, likely contributed to a more vigorous recovery of survivors in this experiment.

The results of this experiment indicate that a single acute disease outbreak is accompanied by long-term compromises in growth performance from both decreased feed intake and increased nutrient partitioning to the immune system.

Table 2. Effect of *Actinobacillus pleuropneumonia* Challenge and Feeding Regimen on Growth Performance in 65- to 120-lb Pigs[a]

	Nonchallenged		*A. pleuropneumonia*					
	Ad Libitum	Pair Fed	Ad Libitum[c]	Ad Libitum	Probability (P <)			
Item[b]	Trt 1	Trt 2	Trt 3	Trt 4	1 vs. 2	2 vs. 3	2 vs. 4	1 vs. 4
Pigs per treatment	7	10	10	30				
D 4 to 7								
ADG, lb	1.96 ± .37	1.67 ± .37	2.04 ± .35	1.84 ± .21	.56	.25	.68	.75
ADFI, lb	3.39 ± .35	3.26 ± .30	3.40 ± .34	3.52 ± .19	.76	.75	.40	.71
G/F	.59 ± .29	.48 ± .29	.60 ± .28	.51 ± .15	.78	.76	.93	.80
D 8 to 11								
ADG, lb	2.38 ± .38	1.42 ± .32	.95 ± .37	1.19 ± .23	.04	.34	.50	.003
ADFI, lb	3.82 ± .35	2.85 ± .30	2.83 ± .34	2.69 ± .20	.02	.99	.64	.003
G/F	.63 ± .29	.42 ± .24	.12 ± .36	.24 ± .17	.56	.54	.52	.22
D 12 to 15								
ADG, lb	2.20 ± .38	1.23 ± .32	1.66 ± .37	1.89 ± .23	.04	.35	.06	.44
ADFI, lb	4.22 ± .35	2.48 ± .30	2.74 ± .34	3.01 ± .21	.001	.57	.11	.001
G/F	.54 ± .29	−.22 ± .24	.001 ± .36	.38 ± .17	.04	.65	.04	.61
D 16 to 19								
ADG, lb	2.93 ± .38	2.43 ± .32	2.50 ± .35	2.68 ± .23	.28	.86	.49	.54
ADFI, lb	4.51 ± .35	3.23 ± .30	3.69 ± .34	3.78 ± .21	.003	.31	.09	.05
G/F	.66 ± .29	.75 ± .24	.64 ± .34	.69 ± .17	.80	.82	.83	.93
D 22 to 25								
ADG, lb	2.64 ± .38	2.54 ± .32	1.94 ± .35	2.13 ± .23	.82	.21	.26	.21
ADFI, lb	5.05 ± .35	4.21 ± .30	4.75 ± .34	4.97 ± .21	.05	.24	.02	.83
G/F	.53 ± .29	.62 ± .24	.42 ± .34	.43 ± .17	.81	.67	.49	.74
D 8 to 25								
ADG, lb	2.55 ± .25	1.92 ± .22	1.78 ± .22	1.92 ± .23	.03	.71	.89	.02
ADFI, lb	4.40 ± .24	3.18 ± .21	3.50 ± .21	3.57 ± .15	.01	.27	.09	.01
G/F	.60 ± .18	.40 ± .16	.31 ± .22	.43 ± .13	.34	.76	.86	.36

[a]Forty seven pigs were used in a randomized incomplete block design with individual pig as the experimental unit. Effects were analyzed using a mixed model with repeated measure.

[b]A challenge effect and a linear time effect were observed for ADG (P<.05). A challenge effect and both linear and quadratic time effects were observed for ADFI (P<.05). This resulted in a tendency for a challenge by time interaction for ADFI (P<.06).

[c]Treatment 3 is a subset of challenged pigs from treatment 4 that were paired with a pair-fed pig in treatment 2.

Table 3. Effect of *Actinobacillus pleuropneumonia* Challenge and Feeding Regimen on Serum Acute Phase Proteins in 65- to 120-lb Pigs[a]

	Nonchallenged		*A. pleuropneumonia*					
	Ad Libitum	Pair Fed	Ad Libitum[c]	Ad Libitum	Probability (P <)			
Item[b]	Trt 1	Trt 2	Trt 3	Trt 4	1 vs. 2	2 vs. 3	2 vs. 4	1 vs. 4
Pigs per treatment	7	10	10	30				
D 5								
Haptoglobin, mg Hgb/dL	49.9 ± 9.0	48.9 ±7.7	53.8 ± 7.6	48.8 ± 5.1	.93	.66	.99	.91
AGP, μg/mL	720 ± 99	570 ± 89	597 ± 87	610 ± 70	.15	.77	.60	.21
Serum amyloid A, μg/mL	13.0 ± 8.2	8.6 ± 6.5	5.6 ± 5.1	5.4 ± 4.2	.67	.62	.66	.39
D 9								
Haptoglobin, mg Hgb/dL	49.4 ± 9.0	50.3 ± 7.7	92.8 ± 7.6	85.3 ± 5.1	.93	.001	.001	.001
AGP, μg/mL	689 ± 99	608 ± 89	628 ± 87	615 ± 71	.44	.83	.93	.41
Serum amyloid A, μg/mL	7.0 ± 8.2	5.1 ± 6.5	35.6 ± 5.1	47.9 ± 4.1	.85	.001	.001	.001
D 13								
Haptoglobin, mg Hgb/dL	42.1 ± 9.0	47.0 ± 7.7	98.4 ± 7.6	102.1 ± 5.5	.66	.001	.001	.001
AGP, μg/mL	676 ± 99	605 ± 89	622 ± 87	563 ± 73	.49	.85	.60	.21
Serum amyloid A, μg/mL	8.1 ± 8.2	8.8 ± 6.5	30.1 ± 5.3	34.0 ± 4.4	.94	.006	.001	.004
D 17								
Haptoglobin, mg Hgb/dL	37.9 ± 9.0	33.3 ± 7.7	59.2 ± 7.9	63.8 ± 5.8	.68	.02	.001	.01
AGP, μg/mL	673 ± 99	483 ± 89	584 ± 89	550 ± 75	.07	.30	.43	.18
Serum amyloid A, μg/mL	1.8 ± 7.8	2.3 ± 6.8	12.0 ± 5.7	10.7 ± 4.7	.97	.26	.28	.30
D 23								
Haptoglobin, mg Hgb/dL	27.5 ± 9.0	32.1 ± 7.7	38.0 ± 7.6	39.8 ± 5.6	.68	.59	.37	.21
AGP, μg/mL	586 ± 99	392 ±89	554 ± 87	488 ± 73	.06	.08	.23	.28
Serum amyloid A, μg/mL	1.5 ± 7.8	6.0 ± 6.5	7.2 ± 5.7	4.7 ± 4.5	.64	.94	.86	.71

[a]Forty seven pigs were used in a randomized incomplete block design with individual pig as the experimental unit. Effects were analyzed using a mixed model with repeated measure.

[b]A challenge effect and a linear time effect were observed for ADG (P<.01). A challenge by time interaction, and linear and quadratic time effects were observed for serum haptoglobin and serum amyloid A (P<.01).

[c]Treatment 3 is a subset of challenged pigs from treatment 4 that were paired with a pair-fed pig in treatment 2.

Table 4. Effect of *Actinobacillus pleuropneumonia* Challenge and Feeding Regimen on Surface Body Temperature (°C) in 65- to 120-lb Pigs[a]

	Nonchallenged		*A. pleuropneumonia*					
	Ad Libitum	Pair Fed	Ad Libitum[c]	Ad Libitum	Probability (P <)			
Item[b]	Trt 1	Trt 2	Trt 3	Trt 4	1 vs. 2	2 vs. 3	2 vs. 4	1 vs. 4
Pigs per treatment	5	7	7	17				
Day								
−1	34.1 ± .4	34.4 ± .4	33.9 ± .4	33.9 ± .3	.50	.52	.14	.62
0	34.5 ± .4	34.2 ± .3	33.3 ± .3	33.3 ± .3	.58	.04	.005	.002
1	34.4 ± .4	34.4 ± .3	34.2 ± .3	34.0 ± .3	.97	.47	.18	.25
4	34.5 ± .4	33.5 ± .4	34.3 ± .4	34.2 ± .3	.04	.23	.07	.40
8	34.3 ± .4	33.2 ± .3	33.6 ± .3	33.7 ± .3	.01	.38	.17	.10
12	35.0 ± .4	33.9 ± .3	34.5 ± .3	34.6 ± .3	.01	.25	.04	.26
14	34.3 ± .4	33.9 ± .3	33.7 ± .3	33.7 ± .3	.38	.67	.48	.11
18	34.0 ± .4	34.1 ± .4	34.2 ± .4	34.2 ± .3	.90	.62	.69	.61

[a]Forty seven pigs were used in a randomized incomplete block design with individual pig as the experimental unit. Effects were analyzed using a mixed model with repeated measure.

[b]A challenge by day effect was observed for average surface body temperature (P<.02).

[c]Treatment 3 is a subset of challenged pigs from treatment 4 that were paired with a pair-fed pig in treatment 2.

EFFECT OF A RESPIRATORY DISEASE CHALLENGE ON NITROGEN RETENTION, IGF-I, ORGAN WEIGHT AND CARCASS CHARACTERISTICS IN GROWING PIGS

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Summary

Forty-seven growing pigs (initially 65 ± 2 lb) were used in a metabolism study to determine the effects of a single respiratory disease challenge on nitrogen retention, plasma insulin-like growth factor-I (IGF-I), organ weight, and carcass characteristics. Thirty pigs were challenged with *Actinobacillus pleuropneumonia*, and 7 pigs were assigned to an ad libitum fed nonchallenged control group. Ten additional nonchallenged pigs were pair-fed the feed intake of a *A. pleuropneumonia*-challenged counterpart. There were five 4 d collection periods (d 4 to 7, d 8 to 11, d 12 to 15, d 16 to 19, and d 22 to 25), and the *A. pleuropneumonia* challenge occurred on d 8. Plasma IGF-I concentrations decreased on d 9 in the disease challenged pigs compared to those in both nonchallenge treatments. Nitrogen retention was decreased during the immune challenge period and only partially recovered by the end of the experiment on d 25. Final organ weights and carcass characteristics were similar among treatments. These results suggest that a single acute respiratory disease challenge is accompanied by partial long-term compromises in protein metabolism and lean growth rate.

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

Introduction

Previous research by our laboratory (KSU 1998 Swine Day, Report of Progress 819) indicated that although short-term decreases in nitrogen (N) balance were evident, long-term effects of an enteric disease challenge by *Salmonella typhimurium* were negligible. Because economically important disease challenges in growing swine are primarily enteric or respiratory, we were curious if a similar immune response pattern in N balance would be evident when *Actinobacillus pleuropneumonia* was used as the respiratory disease agent.

As a continuation of the experiment reported in the preceding article, our objective was to characterize the effects of an acute respiratory disease challenge in pigs by measuring changes in protein metabolism using N balance techniques. Furthermore, we wanted to characterize the changes in insulin-like growth factor-I (IGF-I), organ weights, and carcass characteristics resulting from an acute respiratory disease challenge.

Procedures

The experimental protocol used in this study was approved by the KSU Institutional Animal Care and Use Committee. Forty-seven nonlittermate high-health barrows (PIC C22 × L326; initially 65 ± 2 lb) were obtained from the university swine herd after serological testing to ensure *A. pleuropneumonia* negative status. Pigs were blocked by

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weight and time and allotted to one of three experimental treatments similar to those described in the preceding article.

Daily care, feeding, disease challenge, and diet are all described in the preceding article. There were five 4-d collection periods (d 4 to 7, d 8 to 11, d12 to 15, d 16 to 19, and d 22 to 25) with the *A. pleuropneumonia* challenge occurring on d 8. These periods correlated to prechallenge, challenge, recovery (8 d), and postchallenge. The latter period was selected to be at least 14 d postchallenge.

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

Plasma samples were harvested from blood samples drawn via jugular venipuncture on d 5, 9, 13, 17, and 23 at least 2 h after feeding and analyzed for IGF-I.

All pigs were euthanized humanely on d 27 by intravenous sodium pentobarbitol administration and transported to the KSU veterinary medicine diagnostic laboratory. Each pig was eviscerated, and individual weights were collected for the heart, lungs, stomach, liver, spleen, kidneys, and small intestine. Additionally, 10th rib fat depth and *longissimus* muscle area (LMA) were measured. These data were collected to help determine changes in body composition after recovery from the disease challenge.

All data were analyzed as a randomized incomplete block design using a mixed model procedure with repeated measures. Pigs were blocked by initial weight and time with individual pig as the experimental unit. Periodic samples by pig were used for the repeated measures. Carcass characteristics and organ weights were adjusted covariately for final body weight. Linear and quadratic polynomial contrasts were used to determine the effects of *A. pleuropneumonia* challenge over time on all response criteria. Within the challenge treatment, the challenge pigs that were paired with a control were separated to compare results of disease challenge directly between pigs of similar feed-intake levels.

Table 1. Diet Composition

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

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

Results and Discussion

A disease status effect and a linear time effect were observed for DM digestibility (P<.01; Table 2). A disease status effect and a quadratic time effect were observed for N digestibility (P<.05). The disease status

effect is a result of greater DM and N digestibilities for *A. pleuropneumonia*-challenged pigs compared to control ad libitum-fed pigs from d 8 to 11 and d 22 to 25 (P<.05) and pair-fed control pigs from d 8 to 11 and d 12 to 15 (P<.05). These periodic differences in DM and N digestibilities contributed to the overall d 8 to 25 increased DM and N digestibilities of the *A. pleuropneumonia*-challenged pigs versus both control treatments (P<.01). These increases appear to result from more than changes in DM and N intakes. If feed intake were the primary cause, then pair-fed pigs should have greater digestibility than the ad libitum-fed controls. Because this was not the case, the differences in DM and N digestibilities appear directly associated with changes in immune system activity and most likely are results of physiological changes caused by increased levels of proinflammatory cytokines associated with the immune response.

A disease status by time interaction was observed for N retained (P<.05; Table 3). The interaction resulted from decreased N retention during the acute challenge period and both subsequent recovery periods (d 8 to 19), for both pair-fed controls and the *A. pleuropneumonia*-challenged pigs compared to the ad libitum-fed control pigs. A disease status effect and linear and quadratic time effects were observed for N intake , fecal N, urinary N, and retained N (P<.01). The disease status effect for N intake was due to decreased N intake in the *A. pleuropneumonia* and pair-fed controls versus that of the ad libitum-fed controls (P<.05) from d 8 to 11, 12 to 15, and d 16 to 19. The fecal N effect was due primarily to the decreased intake N from d 8 to 25 for the *A. pleuropneumonia*-challenged pigs (P < .01) and pair-fed pigs (P<.01) compared to that for the ad libitum-fed control pigs. In addition, increased DM digestibility of the *A. pleuropneumonia*-challenged pigs likely contributed to lower fecal N levels compared to that of the ad libitum-fed control pigs.

Urinary N differences resulted from pair-fed pigs having the lowest urinary N levels compared to either the ad libitum-fed controls from d 12 to 25 (P<.04) or the *A. pleuropneumonia*-challenged pigs during d 8 to 11 (P<.04), d 16 to 19 (P<.01), and d 8 to 25 (P<.01). Tendencies for lower urinary N levels of the pair-fed controls compared to the *A. pleuropneumonia*-challenged pigs were observed both from d 12 to 15 (P < .07) and d 22 to 25 (P<.09). Lower urinary N levels of the pair-fed controls compared to the ad libitum-fed controls were associated with decreased N intake in healthy pigs. Although intake N was lower in *A. pleuropneumonia*-challenged pigs compared to ad libitum-fed controls, urinary N was not different (P<.48). This lack of difference indicates that the disease challenge increased muscle breakdown above that associated with inadequate feed intake. The loss of muscle during an immune challenge typically is associated with requirements for amino acids above those supplied by feed intake. The increased amino acids are utilized for increased hepatic protein synthesis to support an immune response to the disease challenge.

Greater N retention was observed for the ad libitum-fed control pigs compared to both *A. pleuropneumonia*-challenged pigs from d 8 to 11 and 12 to 15 (P<.001) and pair-fed controls from d 8 to 11, 12 to 15, and 16 to 19 (P<.03). A tendency for decreased N retention also was observed from d 16 to 19 for *A. pleuropneumonia*-challenged pigs compared to the ad libitum-fed controls (P<.06). The decreased N retention of the different periods after challenge resulted in lower N retention for both *A. pleuropneumonia*-challenged pigs and pair-fed pigs compared to that of the ad libitum-fed pigs from d 8 to 25 (P<.01). Although most of the decreased N retention was a result of decreased N intake, the similarity of d 8 to 25 N retentions between the pair-fed pigs and the *A. pleuropneumonia*-challenged pigs, but different N intakes, further indicate that increased muscle loss likely occurred in the disease-challenge treatment.

A tendency for a quadratic time effect was observed for the percentage of absorbed N retained (P<.08; Table 4). From d 12 to 15, N retention efficiency, both as percentage of

N intake and percentage of absorbed N, was worse for pair-fed pigs (P<.01), with intermediate efficiency for the *A. pleuropneumonia*-challenged pigs (P<.15) versus control ad libitum-fed pigs. Pair-fed control pigs also tended to be worse than *A. pleuropneumonia*-challenged pigs from d 12 to15 (P<.10). The lower N retention efficiency from d 12 to 15 was not apparent when pair-fed controls were compared only to their disease-challenged counterparts (P<.88). The lack of long-term differences in N retention efficiency indicate that changes in N retention are due primarily to differences in N intake. In addition, the increased short-term losses in urinary N associated with the muscle loss from the disease challenge did not appear to be great enough to affect N retention efficiency after challenge.

A disease challenge effect and a quadratic time effect were observed for IGF-I concentrations (P<.03; Table 5). Insulin like growth factor-I levels were lowest for *A. pleuropneumonia*-challenged pigs on d 9 compared to ad libitum-fed control pigs (P<.003) and pair-fed control pigs (P<.001). Insulin like growth factor-I levels of *A. pleuropneumonia*-challenged pigs tended to remain lower than those of ad libitum-fed control pigs through d 17 (P<.10). Pair-fed control pigs tended to have intermediate IGF-I levels, except on d 17, when they tended to be lower than those of the ad libitum-fed controls (P<.10). Insulin like growth factor-I is a growth mediator that is dependent upon several factors for maximum expression, including feed intake. The decreased IGF-I levels of the *A. pleuropneumonia*-challenged pigs and the pair-fed pigs were consistent with decreased feed intake and subsequent decreased N retention associated with the disease challenge and recovery. However, IGF-I levels were not different among treatments by d 23. This indicates that although the *A. pleuropneumonia* challenge did decrease metabolic growth signals during the challenge and recovery, once the disease challenge was overcome, hormonal growth signals likely returned to normal levels. Although IGF-I did return to nonchallenged control levels, the *A. pleuropneumonia*-challenged pigs had different levels of N retention or N intake at d 23, which indicated that they were still recovering from the effects of the disease challenge.

Carcass characteristics and total organ weights were not affected by treatment, except for stomach weight (P<.03; Table 6). Stomach weight was greater for pair-fed control pigs compared to ad libitum-fed controls (P<.01) and *A. pleuropneumonia*-challenged pigs (P<.02). Lung weights were greater for *A. pleuropneumonia*-challenged pigs compared to pair-fed control pigs (P<.05). Higher lung weights were results of some disease-challenge pigs having residual lesions and fluid remaining at the termination of the experiment. Heart weight tended to be greater for ad libitum-fed control pigs compared to *A. pleuropneumonia*-challenged pigs (P<.10). Both liver weight and total organ weight tended to be greater for the ad libitum-fed control pigs compared to the pair-fed control pigs (P<.09).

A major portion of the differences in N balance between *A. pleuropneumonia*-challenged pigs and ad libitum-fed control pigs was due to N intake differences; however, a significant portion also was due to nutrient repartioning to the immune response. The differences in N retention between the pair-fed controls and ad libitum-fed controls indicate the differences in protein metabolism related to N intake. Differences in N intake and urinary N associated with the lack of difference in N retention for the *A. pleuropneumonia*-challenged pigs compared to the pair-fed controls indicate the differences associated with repartitioning nutrients to immune response. The changes in plasma IGF-I are also consistent with the results observed for N retention.

The results of this experiment are consistent with those of previous studies and indicate that protein metabolism, as indicated by N retention, is affected negatively by immune activation. They also indicate that an intranasal dose of 5×10^7 to 1×10^8 cfu of *A. pleuropneumonia* is sufficient to produce an acute immune response. These results further indicate that most of the N balance effects from an acute respiratory immune

challenge on protein metabolism are due to decreased N intake.

In contrast to typical field conditions, the pigs used in this experiment were maintained in a near ideal environment with minimal outside stress and received a similar infectious dose. The lack of additional stresses such as social interaction with pen mates, reinfection from other pigs, and competition for feed and water likely contributed to the vigorous recovery rate for the survivors in this experiment. But even in these near ideal conditions, the pigs were not able to completely recover from the effects of the acute respiratory challenge. This indicates that an acute challenge using *A. pleuropneumonia* will produce effects still apparent 17 d after challenge, which is longer than the period we observed using a *S. typhimurium* challenge model. Finally, changes in N balance from an acute respiratory disease challenge are due to both reductions in N intake and increased muscle loss during nutrient repartitioning for the immune response.

Table 2. Effects of *Actinobacillus pleuropneumonia* Challenge and Feeding Regimen on Dry Matter and Nitrogen Digestibility in 65- to 120-lb Pigs[a]

	Nonchallenged		*A. pleuropneumonia*		Probability (P <)			
Digestibility[b], %	Ad Libitum Trt 1	Pair Fed Trt 2	Ad Libitum[c] Trt 3	Ad Libitum Trt 4	1 vs. 2	2 vs. 3	2 vs. 4	1vs. 4
Pigs per treatment	7	10	10	30				
D 4 to 7								
Dry matter	87.4 ± 1.2	88. ± 11.1	87.51 ± .2	86.8. ± 9	.56	.61	.17	.61
Nitrogen	81.6 ± 1.5	82.6 ± 1.3	82.6 ± 1.5	82.1 ± 1.0	.54	.92	.66	.74
D 8 to 11								
Dry matter	85.9 ± 1.2	85.8 ± 1.1	87.4 ± 1.2	87. ± 9.9	.92	.28	.03	.06
Nitrogen	83.0 ± 1.5	83.4 ± 1.3	86.5 ± 1.5	86.6 ± 1.0	.84	.08	.008	.01
D 12 to 15								
Dry matter	86.1 ± 1.2	85.1 ± 1.1	86.4 ± 1.2	87.0. ± 9	.41	.41	.05	.44
Nitrogen	83.7 ± 1.5	83.1 ± 1.3	85.5 ± 1.5	85.7 ± 1.1	.72	.18	.04	.15
D 16 to 19								
Dry matter	85.6 ± 1.2	85.7 ± 1.1	86.6 ± 1.2	86.9. ± 9	.93	.59	.22	.24
Nitrogen	83.21 ± .5	84.4 ± 1.3	85.7 ± 1.5	85.3 ± 1.1	.47	.48	.44	.13
D 22 to 25								
Dry matter	84.2 ± 1.2	85.4 ± 1.1	86.81 ± .2	87.0. ± 9	.35	.35	.09	.02
Nitrogen	81.81 ± .5	83.8 ± 1.3	86.1 ± 1.5	85.7 ± 1.1	.21	.21	.12	.006
D 8 to 25								
Dry matter	85.5. ± 8	85.6 ± .7	86.8 ± .9	87.0. ± 7	.93	.09	.002	.004
Nitrogen	82.9 ± 1.1	83.6 ± 1.0	85.91 ± .1	85.9. ± 9	.38	.01	.001	.001

[a]Forty seven pigs were used in a randomized incomplete block design with individual pig as the experimental unit. Effects were analyzed using a mixed model with repeated measures.

[b]A challenge effect, and a linear time effect were observed for DM digestibility (P<.01). A challenge effect and a quadratic time effect were observed for N digestibility (P<.05).

[c]Treatment 3 is a subset of challenged pigs from treatment 4 that were paired with a pair-fed pig in treatment 2.

Table 3. Effect of *Actinobacillus pleuropneumonia* Challenge and Feeding Regimen on Nitrogen Balance in 65- to 120-lb Pigs[a]

	Nonchallenged		*A. pleuropneumonia*		Probability (P <)			
Item[b], g/d	Ad Libitum Trt 1	Pair Fed Trt 2	Ad Libitum[c] Trt 3	Ad Libitum Trt 4	1 vs. 2	2 vs. 3	2 vs. 4	1vs. 4
Pigs per treatment	7	10	10	30				
D 4 to 7								
N intake	53.4 ± 5.4	51.4 ± 4.6	53.5 ± 5.3	55.73 ± .1	.76	.39	.75	.70
Fecal N	9.7 ± 1.1	8.9 ± .95	9.3 ± 1.1	10.0 ± .58	.61	.31	.79	.77
Urine N	12.9 ± 2.4	12.9 ± 2.1	15.2 ± 2.2	14.7 ± 1.6	.99	.35	.44	.41
N retained	30.8 ± 3.4	29.5 ± 2.9	28.8 ± 3.1	31.0 ± 2.0	.74	.63	.99	.97
D 8 to 11								
N intake	60.25 ± .4	44.8 ± 4.6	48.5 ± 5.6	44.8 ± 3.2	.02	.99	.60	.008
Fecal N	10.0 ± 1.1	7.3. ± 95	6.61 ± .2	6.1 ± .61	.07	.29	.69	.003
Urine N	16.2 ± 2.4	12.8 ± 2.1	18.8 ± 2.2	17.2 ± 1.7	.19	.03	.04	.67
N retained	33.9 ± 3.4	24.7 ± 2.9	23.0 ± 3.2	21.6 ± 2.1	.03	.33	.81	.001
D 12 to 15								
N intake	66.6 ± 5.4	39.1 ± 4.6	43.2 ± 5.3	47.6 ± 3.3	.001	.10	.56	.001
Fecal N	10.7 ± 1.1	6.2 ± .95	6.21 ± .1	6.8 ± .62	.002	.57	.98	.003
Urine N	17.7 ± 2.4	12.5 ± 2.1	17.8 ± 2.2	17.4 ± 1.7	.04	.01	.07	.89
N retained	38.1 ± 3.4	20.4 ± 2.9	19.2 ± 3.1	23.4 ± 2.1	.001	.34	.89	.001
D 16 to 19								
N intake	71.1 ± 5.4	50.8 ± 4.6	58.2 ± 5.3	59.8 ± 3.3	.003	.08	.30	.05
Fecal N	11.7 ± 1.1	8.2 ± .95	9.0 ± 1.1	9.1 ± .63	.02	.42	.62	.04
Urine N	22.5 ± 2.4	15.5 ± 2.1	22.5 ± 2.2	20.7 ± 1.7	.006	.008	.01	.43
N retained	36.8 ± 3.4	27.1 ± 2.9	26.7 ± 3.1	30.0 ± 2.2	.02	.36	.98	.06
D 22 to 25								
N intake	79.6 ± 5.4	66.3 ± 4.6	74.9 ± 5.3	78.4 ± 3.3	.05	.01	.23	.84
Fecal N	14.3 ± 1.1	10.9 ± .95	10.8 ± 1.1	11.4 ± .63	.02	.64	.98	.02
Urine N	29.6 ± 2.4	23.6 ± 2.1	28.3 ± 2.2	26.9 ± 1.7	.02	.10	.09	.23
N retained	35.6 ± 3.4	31.7 ± 2.9	35.63.1	40.2 ± 2.2	.35	.009	.60	.21
D 8 to 25								
N intake	69.2 ± 3.7	50.1 ± 3.2	56.3 ± 3.3	57.3 ± 2.3	.001	.18	.05	.004
Fecal N	11.7 ± .7	8.1 ± .6	8.2 ± .7	8.3 ± .4	.001	.94	.82	.001
Urine N	21.5 ± 1.8	16.1 ± 1.7	21.9 ± 1.5	20.4 ± 1.4	.002	.002	.002	.48
N retained	36.1 ± 2.4	26.0 ± 2.1	26.2 ± 1.8	28.6 ± 1.7	.001	.76	.21	.002

[a]Forty seven pigs were used in a randomized incomplete block design with individual pig as the experimental unit. Effects were analyzed using a mixed model with repeated measures. [b]A challenge effect and both linear and quadratic time effects were observed for N intake, fecal N, urine N, and retained N (P<.01). A challenge × time interaction was observed for retained N (P<.01). [c]Treatment 3 is a subset of challenged pigs from treatment 4 that were paired with a pair-fed pig in treatment 2.

Table 4. Effect of *Actinobacillus pleuropneumonia* Challenge and Feeding Regimen on Nitrogen Retention Efficiency in 65- to 120-lb Pigs[a]

	Nonchallenged		*A. pleuropneumonia*		Probability (P <)			
Efficiency[b], %	Ad Libitum Trt 1	Pair Fed Trt 2	Ad Libitum[c] Trt 3	Ad Libitum Trt 4	1 vs. 2	2 vs. 3	2 vs. 4	1vs. 4
Pigs per treatment	7	10	10	30				
D 4 to 7								
% of ADFI	57.71 ± 1.8	57.7 ± 9.9	54.4 ± 13.9	55.6 ± 6.2	.99	.88	.85	.87
% of absorbed	70.6 ± 15.5	69.7 ± 13.0	65.8 ± 18.4	67.9 ± 8.0	.96	.90	.90	.87
D 8 to 11								
% of ADFI	56.4 ± 11.8	53.3 ± 9.9	45.2 ± 14.6	43.8 ± 6.5	.84	.71	.41	.34
% of absorbed	67.8 ± 15.5	63.8 ± 13.0	52.3 ± 19.4	50.9 ± 8.5	.84	.68	.40	.33
D 12 to 15								
% of ADFI	57.3 ± 11.8	18.8 ± 9.9	19.0 ± 13.9	38.1 ± 6.6	.01	.97	.10	.15
% of absorbed	68.5 ± 15.5	16.0 ± 13.0	19.3 ± 18.4	43.3 ± 8.6	.009	.88	.08	.15
D 16 to 19								
% of ADFI	52.2 ± 11.8	50.7 ± 9.9	45.0 ± 13.9	50.1 ± 6.8	.92	.79	.96	.87
% of absorbed	62.6 ± 15.5	60.1 ± 13.0	52.9 ± 18.4	59.0 ± 8.8	.90	.80	.94	.84
D 22 to 25								
% of ADFI	45.0 ± 11.8	48.1 ± 9.9	48.7 ± 13.9	51.86 ± .8	.84	.95	.75	.61
% of absorbed	55.0 ± 15.5	57.2 ± 13.0	56.6 ± 18.4	60.6 ± 8.8	.91	.99	.82	.75
D 8 to 25								
% of ADFI	52.8 ± 7.1	42.8 ± 6.1	39.5 ± 8.4	45.8 ± 4.5	.24	.79	.66	.35
% of absorbed	63.6 ± 9.2	49.4 ± 7.9	45.3 ± 11.0	53.2 ± 5.7	.21	.81	.67	.30

[a]Forty seven pigs were used in a randomized incomplete block design with individual pig as the experimental unit. Effects were analyzed using a mixed model with repeated measures.

[b]A tendency for a quadratic time effect was observed for efficiency of absorbed nitrogen (P<.08).

[c]Treatment 3 is a subset of challenged pigs from treatment 4 that were paired with a pair-fed pig in treatment 2.

Table 5. Effect of *Actinobacillus pleuropneumonia* Challenge and Feeding Regimen on Plasma IGF-I and Serum Acute Phase Proteins in 65- to 120-lb Pigs[a]

	Nonchallenged		*A. pleuropneumonia*		Probability (P <)			
Item	Ad Libitum Trt 1	Pair Fed Trt 2	Ad Libitum[c] Trt 3	Ad Libitum Trt 4	1 vs. 2	2 vs. 3	2 vs. 4	1vs. 4
Pigs per treatment	7	10	10	30				
D 5								
IGF-I, ng/mL	2383 ± 7	274 ± 34	238 ± 41	2402 ± 2	.45	.41	.34	.98
D 9								
IGF-I, ng/mL	274 ± 37	275 ± 34	187 ± 39	155 ± 22	.96	.05	.001	.003
D 13								
IGF-I, ng/mL	239 ± 37	221 ± 34	156 ± 39	173 ± 23	.70	.13	.17	.10
D 17								
IGF-I, ng/mL	306 ± 37	228 ± 34	238 ± 41	236 ± 24	.10	.99	.84	.08
D 23								
IGF-I, ng/mL	288 ± 37	270 ± 34	247 ± 39	263 ± 24	.70	.54	.85	.54

[a]Forty seven pigs were used in a randomized incomplete block design with individual pig as the experimental unit. Effects were analyzed using a mixed model with repeated measures.

[b]A challenge effect and a quadratic time effect were observed for IGF-I (P<.03).

[c]Treatment 3 is a subset of challenged pigs from treatment 4 that were paired with a pair-fed pig in treatment 2.

Table 6. Effect of *Actinobacillus pleuropneumonia* Challenge and Feeding Regimen on Carcass Characteristics and Organ Weights in 65- to 120-lb Pigs[a]

	Nonchallenged		*A. pleuropneumonia*		Probability (P <)			
Item[b]	Ad Libitum Trt 1	Pair Fed Trt 2	Ad Libitum[c] Trt 3	Ad Libitum Trt 4	1 vs. 2	2 vs. 3	2 vs. 4	1vs. 4
Pigs per treatment	5	7	7	17				
D 27 10th rib BF, in	.45 ± .05	.38 ± .05	.36 ± .07	.38 ± .03	.30	.87	.93	.20
D 27 LMA, in^2	4.96 ± .21	5.04 ± .18	4.52 ± .18	4.80 ± .11	.78	.10	.24	.48
Organ wt, g								
Heart	332 ± 32	280 ± 28	296 ± 22	277 ± 21	.19	.55	.90	.10
Liver	1605 ± 98	1440 ± 90	1564 ± 123	1516 ± 78	.09	.13	.30	.29
Spleen	204 ± 35	190 ± 30	164 ± 34	169 ± 22	.75	.52	.53	.36
Kidneys	315 ± 22	313 ± 18	337 ± 14	322 ± 12	.94	.26	.66	.77
Lungs	685 ± 87	596 ± 72	788 ± 72	768 ± 47	.45	.07	.05	.41
Stomach	335 ± 16	386 ± 16	359 ± 7	372 ± 12	.01	.19	.36	.02
Small Intestine	1284 ± 95	1370 ± 86	1306 ± 63	1387 ± 73	.38	.78	.81	.22
Total Organ Wt.	4891 ± 190	4441 ± 177	4798 ± 175	4727 ± 100	.09	.16	.17	.45
Organs as % BW	9.35 ± .63	9.46 ± .62	10.1 ± .56	9.79 ± .54	.84	.41	.49	.36

[a]Forty seven pigs were used in a randomized incomplete block design with individual pig as the experimental unit. Effects were analyzed using a mixed model.

[b]A challenge effect was observed for stomach weight (P<.03).

[c]Treatment 3 is a subset of challenged pigs from treatment 4 that were paired with a pair-fed pig in treatment 2.

INFRARED THERMOGRAPHY OF SWINE BODY SURFACE TEMPERATURES AND ASSOCIATED RECTAL TEMPERATURES DURING AN ACUTE RESPIRATORY DISEASE CHALLENGE

J. A. Loughmiller, M. F. Spire[1], S. S. Dritz[1], B. W. Fenwick[2], S. Hogge[1], and J. Foster[1]

Summary

An acute *Actinobacillus pleuropneumonia* challenge was used to study changes in rectal and radiant surface temperatures over 18 h. From 3.5 to 15 h after challenge, rectal temperatures were elevated in challenged pigs compared to nonchallenged controls. From 6 through 18 h after challenge, infrared surface temperature was higher for challenged pigs versus control nonchallenged pigs. Correlation coefficient analysis indicated that surface temperature and rectal temperature were moderately correlated. These results indicate that infrared thermography will detect changes in body surface temperature associated with the acute phase febrile response and has potential as a diagnostic tool for assessing systemic changes in radiant heat production.

(Key Words: Fever, Infrared Thermography, Rectal Temperature.)

Introduction

Recent interest has been shown regarding the potential of infrared thermography (IRT) to detect the febrile response during the onset of disease or inflammation prior to expression of severe clinical symptoms. Infrared thermography measures changes in radiant body surface temperature caused by alterations in blood flow underlying the skin that leads to variation in the heat flow to the skin surface. It has the advantage of being a passive, noninvasive, remote temperature-sensing device. The use of IRT as a screening tool would enhance the diagnostic capabilities of veterinarians and producers to assess an animal's clinical condition during an acute disease outbreak. Because of these characteristics, IRT may be a better temperature-sensing tool for pigs in group housing that are not conditioned to prolonged human contact associated with more traditional temperature sensing methods like rectal probes.

During the rising phase of fever (i.e., as the body temperature is increasing), an animal's heat production is increased by heat-generating physiological reflexes and behavioral changes. Simultaneously, the amount of heat loss is decreased, primarily by peripheral vasoconstriction. Because of the decrease in initial heat loss, it is unknown if the changes in internal heat production can be detected by measuring changes in surface body temperature. In this study, an infrared radiometer was used to measure radiated, photonic energy at the skin surface following challenge with the respiratory pathogen, *Actinobacillus pleuropneumonia*. The characterization of the febrile response at the body surface was compared to thermal profiles of nonchallenged pigs under similar environmental and nutritional conditions.

Procedures

The experimental protocol used in this study was approved by the KSU Institutional Animal Care and Use Committee. Twenty-four pigs (initially 65 ± 2 lb) were blocked by initial weight in a randomized incomplete

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block design with pig as the experimental unit. Each pig was allotted to either the disease challenged or unchallenged control treatment. Within the disease challenge treatment, pigs were subdivided further into two treatments based upon febrile response. Pigs exhibiting a 3°F increase in rectal temperature after challenge were categorized as the febrile-challenged group, and the remainder were categorized as the nonfebrile-challenged group. There were 12 unchallenged controls, 6 febrile-challenged, and 6 nonfebrile-challenged pigs. All pigs were housed in stainless steel metabolism crates in an environmentally controlled room held at 70°F with constant lighting. Pigs were given a 3 d acclimation period and were allowed feed and water ad libitum. Diet composition is shown in Table 1. Feed was removed 4 h before challenge to minimize differences in body temperature associated with different feed-intake patterns among the pigs.

Table 1. Diet Composition

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

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

The pigs were verified *A. pleuropneumonia* negative by serological testing prior to being selected for this experiment. *Actinobacillus pleuropneumonia* was administered via intranasal inoculation of 3 mL of culture medium containing 10^7 cfu *A. pleuropneumonia*, and control pigs were given 3 mL of sterile media via intranasal administration.

Infrared thermographs were taken approximately 9 ft perpendicular to the left side of each pig using a stationary thermal imaging camera (3-5 μm wavelength) equipped with a 16° FOV lens having images displayed as a 256 × 256 pixel focal plane array. Images were analyzed by a certified technician to determine mean surface body temperature. Rectal temperatures were taken simultaneously, and both IRT and rectal temperatures were collected at -2 and -1 h before challenge, and 0 h (at challenge), every 15 minutes until 6 h after challenge, then every 3 h from 9 to 18 h after challenge.

All data were analyzed as a randomized incomplete block design using a mixed model with repeated measures. Pigs were blocked by initial weight and time, with individual pig as the experimental unit. Time period was used for the repeated measures. Rectal and IRT surface temperatures were analyzed for time × treatment interactions and their associated main effects. A Spearman correlation analysis measured the strength of the relationship between increases in rectal temperature and surface temperature.

Results and Discussion

A treatment × time interaction was observed for rectal temperature ($P<.01$; Figure 1). The interaction was due to observed differences in rectal temperature from 3.5 h to 15 h after challenge. In that period, rectal temperatures for febrile and nonfebrile pigs were elevated compared to those of the control pigs ($P<.02$). In addition, from 5.25 to 18 h after challenge, rectal temperature for febrile pigs remained elevated compared to those for both control and nonfebrile pigs ($P<.01$).

Treatment and time effects were observed for pig surface temperature ($P<.01$; Figure 2). From 6 through 18 h after challenge, surface temperature was higher for febrile versus control pigs ($P<.01$), and except for 9 h after challenge, for febrile versus nonfebrile pigs ($P<.05$). Surface temperature was not different for control versus nonfebrile pigs ($P>.12$) throughout the experiment. The Spearman correlation of rectal temperature and surface temperature was $r = .52$ ($P<.01$) throughout the 18 h period. Additionally, a linear relationship was observed for increasing surface tempera-

ture as rectal temperature increased in febrile pigs r = .50; P<.01; Figure 3).

Our results indicate that although differences exist in the time course of increasing rectal and surface temperatures, use of IRT appears to be an effective method to detect changes in body temperature associated with the febrile response. The 2.5 h time difference between rising rectal and surface body temperatures is due to the cooler skin temperatures while body heat is retained internally during the building fever and the time necessary for the increased internal heat to migrate to the external surfaces.

Rectal temperatures typically have been associated with assessment of the febrile state in domestic livestock. However, obtaining an accurate indication of temperature in animals not conditioned to frequent handling often is difficult. Anecdotal evidence from our laboratory suggests that rectal temperatures taken in clinically normal 30 lb pigs that were removed from their pen and restrained typically exceeds 103.5EF within 1 min of restraint. Because of this variability, rectal temperatures may not be collected in group-housed suspect pigs that are still active and avoiding human contact. The use of rectal temperatures typically is associated with individually penned pigs or group-housed pigs that are exhibiting lethargy, somnolence, and other indicators of severe clinical stress.

The use of IRT to detect changes in body temperature provides an avenue of early temperature assessment that is noninvasive, rapid, and positively correlated with changes in core body temperature. In conclusion, this research indicates that IRT can detect changes in body temperature associated with a febrile response to disease and has potential as a diagnostic tool for assessing systemic changes in radiant heat production.

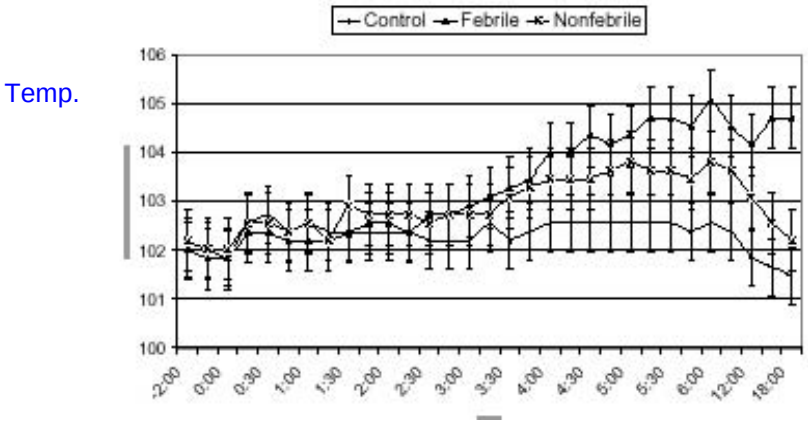

Figure 1. Effect of an Acute Respiratory Disease Challenge in 65 lb Pigs on 18-h Changes in Rectal Temperature, EF.

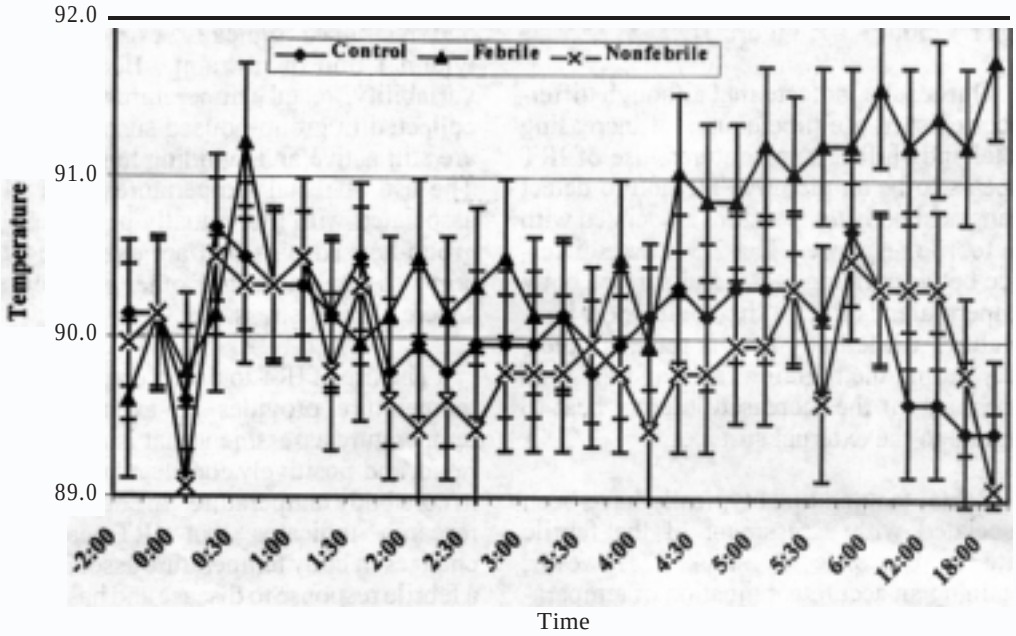

Figure 2. **Effect of Acute Respiratory Disease Challenge in 65-lb Pigs on 18-h Changes in Radiant Surface Temperature, °F.**

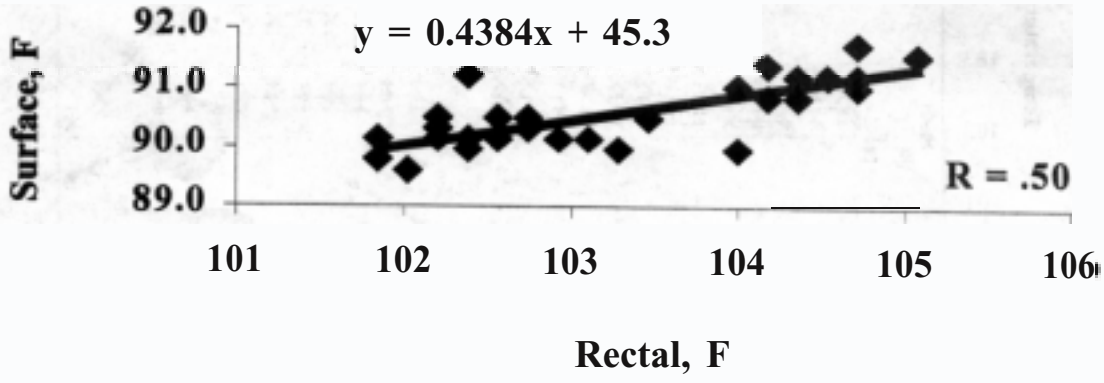

Figure 3. **Relationship between Increased Rectal Temperature and Increased Body Surface Temperature in A. pleuropneumonia-Challenged Pigs Exhibiting a Fever.**

ADDITIONAL L-CARNITINE IN THE GESTATING SOW DIET IMPROVES CARCASS CHARACTERISTICS OF THE OFFSPRING[1]

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Summary

A total of 232 sows was used to determine the effects of an additional 50 ppm of L-carnitine in the gestation diet on sow and offspring performance. No differences were observed in either the immediate or subsequent number of pigs born or born alive per litter (P>.10). No differences were observed in pig weight at birth, weaning, or d 60 of age. Muscle fiber analysis of newborn pigs indicated a tendency for a larger cross-sectional area of the semitendinosus muscle; increased primary (slow-twitch, red) fibers; and a higher ratio of primary to secondary fibers (fast-twitch, white). No differences were observed in the hot carcass weight, but loin depth and percentage lean were increased in offspring of sows fed L-carnitine during gestation. Therefore, although feeding L-carnitine during gestation had no effect on the number of pigs born, it improved carcass leanness of the offspring consistent with changes in muscle fiber characteristics. More research is needed to determine the optimum level of L-carnitine to use in the gestation diet.

(Key Words: L-Carnitine, Gestation, Muscle Development)

Introduction

L-carnitine affects several key enzymes involved in protein and lipid metabolism**;** therefore, it may enhance productivity of the gestating sow. Previous research has shown that added L-carnitine in the gestating sow diet increased maternal IGF-I concentrations on days 60 and 90 of gestation. Research also has shown that both IGF-I and insulin are key factors that influence muscle development in the fetal pig. Studies have focused on treatments that affect fetal muscle development because muscle fiber hyperplasia (increasing cell number) is completed by birth. European researchers have reported a correlation between muscle fiber number and ADG (average daily gain) from d 70 to 130. Therefore, this experiment was designed to determine the effect of adding 50 ppm L-carnitine to the gestating sow diet on the number of pigs born alive, fetal muscle development, and carcass characteristics of the offspring.

Procedures

The experiment was conducted on a 3,000 sow farrow-to-wean operation in southwest Minnesota and utilized 232 sows (PIC Line C22). Sows were assigned to treatment on d 1 of gestation. Sows were fed a gestation diet (.7% lysine, 1.0% Ca, and

[1]The authors thank Dave Logan, Linda Flanagan, Jay Schiebout, and Richard Feucht of Global Ventures, Inc., for their assistance in animal care, data collection, and partial funding and Lonza Inc., Fair Lawn, NJ, for partial funding.

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

[4]Lonza, Inc., Fair Lawn, NJ.

[5]Global Ventures, I, Inc., Pipestone, MN.

.90% P; Table 1) with or without 50 ppm L-carnitine. Sows were fed 4 lb/d until day 100 of gestation, after which they were fed 6 lb/d until moved to the farrowing facility and dietary treatments ceased.

Table 1. Gestation Diet Composition[a]

Ingredient	Percent[b]
Corn	74.9
Soybean meal (46.5%)	15.6
Alfalfa meal	5.0
Other vitamin and trace mineral additions	4.5
Total	100.0

[a]Sows were fed 4 lb/d.

[b]Formulated to contain .7% lysine, 1.0% Ca, and .90% P.

At farrowing, the numbers of pigs born alive, stillborn, and mummified were recorded. A subsample (15 litters/treat-ment) were weighed at birth. Of the sub-sample, 181 pigs (4 per litter) were tagged and weighed at weaning and at the end of the nursery phase (42 lb). The third lightest gilt from 15 litters per treatment was euthanized, and the semitendinosus muscle was removed from the right side. This is one of few muscles in which the fibers run through the entire length, allowing for accurate counting by examining the muscle in cross-section. The muscle was weighed, and three sections (5 mm in depth and a complete cross-section of the muscle) were removed from the mid-belly of the muscle. Segments were placed on a piece of cork, covered with a protective coating, and snap frozen in isopentane that had been cooled on dry ice. Samples were stored in a ultralow freezer (-80°C) until analysis. Cross-sections (10 microns) were placed on a microscope slide and stained for myosin adenosine triphosphate (ATPase) activity**.** The procedure was optimized for our laboratory conditions and used a pre-incubation of pH 4.2 and ATP incubation of pH 9.4. Once staining was completed, images were taken at 400 X moving from the light side to the darker stained side of the semitendinosus (approximately 30 views). Images were captured with a Nipikon™ microscope with a 40 power lens and a 10 power optical with the Optimas™ system, then images were imported into Optimas™ 5.2 software program. Once images were saved, fibers were counted as primary (stained dark) and secondary (stained light) in the software program of Paintbrush™. Approximately 1 to 2% (3,000 to 5,000 fibers / pig) of the cross-section was counted (15 to 20 frames). After fibers were counted, an overall area of the cross-section was determined by an overhead view of the slide. Total fiber number was determined by multiplying the average number of primary and secondary fibers in each square mm by the overall area in sq mm of the muscle.

Pigs were ear notched at birth according to the maternal treatment in gestation and then were standardized across treatments. At weaning, pigs were mixed within sex and moved to offsite nurseries. Pigs were moved to finishing buildings at 60 days of age. As pigs reached market weight (270 lb), they were sorted and marketed by treatment and sex for a total of four different marketing groups (i.e., a load of barrows or gilts from each individual treatment). At the slaughter plant, experimental pigs were processed at the beginning of the day to decrease the potential variation in Fat-O-Meter™ measurements from operator fatigue. Individual carcass measurements were obtained on 1,256 pigs.

Data were analyzed using the GLM procedure of SAS. Sow was used as the experimental unit for the analysis of the farrowing data and parity as a covariate. The means for the subsequent farrowing performance were adjusted for both parity and the previous number of pigs born per litter. In the analysis of the muscle fiber data, sow was used as the experimental unit and one pig per sow. Analysis of both pig weight gain and carcass characteristics used pig as the experimental unit. The mean for hot carcass weight was adjusted with age at slaughter as the covariate. Hot carcass

weight was used as the covariate for the analysis of the remaining carcass characteristics.

Results and Discussion

No differences were observed in the initial or subsequent farrowing performance of sows fed supplemental L-carnitine (Table 2). Although previous research at Kansas State University observed increases in the number of pigs born alive per litter, no changes were observed in this experiment with regards to the number of pigs born, born alive, or born dead (stillborn and mummified) per litter (P>.10). No differences (P>.10; Table 2) were observed in pig weight at birth, weaning, or at the end of the nursery phase (d 60).

The analysis of the newborn pigs for muscle fiber number as an indicator of fetal muscle development showed trends (P = .15) for increased cross-sectional area of the semitendinosus muscle and increased number of primary (slow-twitch, red) fibers in the S.T. muscle (Table 3). A trend (P = .11) in changes of the secondary:primary fiber ratio also existed, indicating a possible change to a muscle with more primary (slow-twitch, red) fibers compared to control offspring.

Pigs from sows fed 50 ppm supplemental L-carnitine during gestation had less backfat (P<.01; Table 4), greater loin depth (P<.01), and a higher percentage lean (P<.01). No differences was observed in hot carcass weight (P>.10). A difference in age at slaughter was observed, with control pigs being 1.6 days younger on average; therefore, age was used as a covariate for hot carcass weight.

The results of this experiment indicated no difference in the number of pigs born in the subsequent farrowing. However, numerical trends existed for pigs from sows fed added L-carnitine to have increased semitendinosus muscle area and primary fiber numbers. Improvements were observed in the percentage lean and loin depth of the offspring from sows fed added L-carnitine during gestation and correspond to the changes in muscle fiber development observed at birth. More research is needed to help support the effect of L-carnitine on fetal muscle development and to determine the optimum level to add in the gestation diet.

Table 2. Effect of L-Carnitine Supplementation on Sow and Litter Performance

	L-Carnitine			
Item	0 ppm	50 ppm	SEM	P <
No. sows				
Average parity	2.73	2.75	.06	.77
Number of Pigs per Litter[a]				
Total born	12.93	12.41	.90	.25
Born alive	11.54	11.13	.92	.34
Born dead	1.38	1.29	.47	.69
Subsequent Number of Pigs per Litter[b]				
Total born	13.15	13.1	.92	.91
Born alive	11.60	11.29	.90	.48
Born dead	1.58	1.83	.52	.31
No. pigs	87	94		
Average Pig Weight, lb[a]				
Birth	3.40	3.56	.07	.15
Weaning	11.82	12.06	.43	.65
Nursery	43.04	40.78	1.22	.21
Nursery age, d	59.22	59.30	.49	.91
Birth to nursery ADG, lb/d	.67	.62	.02	.12

[a]Means were adjusted for parity by covariate analyses.
[b]Means were adjusted for parity and previous number born by covariate analyses.

Table 3. Effects of L-Carnitine Supplementation during Gestation on Fetal Muscle Fiber Development

	L-Carnitine			
Item	0 ppm	50 ppm	P <	SEM
No. of pigs	13	15		
Total fibers per mm^2	3913	3634	.45	264
Area per muscle, mm^2	112	128	.15	8.1
Total fibers per pig[a]	431,001	463,711	.43	31,155
Total primary fibers	39,609	47,664	.15	4,098
Total secondary fibers	391,367	417,150	.54	31,297
Secondary:Primary ratio	12.46	9.20	.11	1.43

[a]Represents total number of fibers located in the semitendinosus muscle of the pig.

Table 4. Effects of L-Carnitine Supplementation during Gestation on Offspring Carcass Characteristics

	L-Carnitine			
Item	0 ppm	50 ppm	P <	SEM
No. of pigs	671	585		
Age, d	178.0	179.6	.0001	.14
Hot carcass weight, lb[a]	193.6	193.0	.62	.76
10^{th} rib fat depth, mm[b]	18.44	17.83	.003	.15
Loin depth, mm[b]	57.0	59.37	.0001	.27
Percentage lean,%[b,c]	54.45	55.1	.0001	.102
Fat free lean index[b,c]	49.4	49.69	.003	.073
New fat free lean, lb[b,d]	110.21	111.22	.0001	.557
New fat free lean percentage,%[b,e]	57.14	57.64	.0001	.09

[a]Means were adjusted for age at slaughter by covariate analyses.
[b]Means were adjusted for hot carcass weight by covariate analyses.
[c]Represents plant calculated values.
[d]Calculated as 17.2668 – 27.9344 * BF(in) + 3.5468 * LD(in) + 0.5449 * HCW(lb).
[e]Calculated as (lb FFL/HCW) * 100.

EFFECTS OF CHROMIUM PICOLINATE ON REPRODUCTION AND FARROWING PERFORMANCE OF PARITY ONE SOWS[1]

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

Summary

We examined the influence of chromium picolinate fed to gilts during the growing phase from 50 lb through their first farrowing on reproductive and farrowing performance. No differences were detected in first service farrowing rate or total or live born litter size. These data fail to support a positive influence of chromium picolinate fed during development and gestation on reproductive and farrowing performance of parity 1 sows.

(Key Words: Sows, Chromium Picolinate, Litter Size, Gilt Development.)

Introduction

Chromium is a trace mineral normally thought to be present in adequate quantities in normal swine diets. However, recent research suggests that adding chromium to swine diets will lead to improved farrowing rates and increased litter sizes. Chromium also has been shown to influence the production of insulin, which is an important hormone that affects both growth and reproduction. Other research has indicated that dietary chromium supplementation will result in enhanced immune function. Several reports have indicated that chromium supplementation must occur for a fairly long period of time before the litter size increases are observed. The objective of this study was to examine the influence of chromium picolinate fed during development and gestation on reproductive and farrowing performance of parity 1 sows.

Procedures

Gilts were fed the standard diets for the farm or the standard diet supplemented with 200 ppb of chromium from chromium picolinate. These diets were corn and soybean meal-based; dietary specifications are listed in Table 1. Added trace minerals and vitamins were similar to KSU standard recommendations. The supplemental chromium was fed to gilts from 50 lb (placement in the finishing barn) through farrowing their first litter. During gilt development, every other room (600 hd per room) was fed supplemental chromium. Each room was filled approximately every 4 weeks. Gilts were transferred from the gilt multiplier to the commercial production sow farms in groups of approximately 25 per week. Gilts were moved to the commercial sow farm site (two 1,500-sow farms on the same site), held in an acclimation room, and heat checked daily. All gilts were bred by artificial insemination and were placed in gestation stalls immediately after breeding. They remained in the same stall until they were either detected open or moved to the farrowing house on d 112 of gestation.

During development and acclimation, the chromium-supplemented feed contained 200 ppb of chromium from chromium picolinate. Gilts were full-fed during development and

[1]We acknowledge the employees in the Pipestone System who provided technical assistance with this project and Prince Agri Products, Quincy, IL, for partial financial support.

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

acclimation. During gestation, all gilts receiving chromium were fed 1 tablespoon of a topdressing each day. It was formulated to provide 200 ppb for an ADFI of 5 lb. Gilts were fed according to body condition (4 to 6 lb) during gestation.

After each group of gilts was transferred, the gilts were assigned a unique alternate ID for each treatment, and all breeding and farrowing performance data were entered into a PigChamp database. The data then were extracted from the PigChamp and exported into a spreadsheet for analysis. All sows that did not conceive or farrow on the first service were assigned a removal reason of recycle and removed from the experiment.

Eight records were removed from the chromium-supplemented group that indicated a first service date but neither a farrowing date nor removal date. One record was removed because gestation length was less than 80 d and six records because the gestation length was greater than 140 d. Therefore, the conception probably was not the result of the recorded service. One duplicate record was removed that had the same entries for all variables, and one pair of duplicate records was removed because the alternate ID's were the same and the primary ID's were different. Nineteen of the control gilts were removed because service age and transfer ages were the same, indicating that transfer age was not accurate.

Transfer age, age at first service, gestation length, and total and live born litter sizes were analyzed as continuous variables with a general linear model that contained treatment, farm, and the interaction between farm and treatment. Culling rate before first service and first service farrowing rate were analyzed as categorical data using a chi square analysis. Gestation length was examined, because several farms in the system had clinical porcine respiratory reproductive syndrome (PRRS) outbreaks during the study period. One of the major signs of clinical PRRS is farrowing early, and chromium supplementation is not known to affect gestation length. Therefore, an effect on gestation would be supportive evidence of active clinical PRRS during the study period.

Table 1. Summary of Diet Specifications

Weight	Lysine, %	Added Fat, %	Lysine, g/ Mcal ME	Ca %	P %	Av. P%
16-26 lb	1.35	3	4.0	1.15	.95	.61
26-45 lb	1.30	3	3.9	.84	.80	.49
45-75 lb	1.20	0	3.7	.83	.79	.48
75-125 lb	1.10	0	3.3	.84	.71	.40
125-170 lb	1.00	0	2.9	.65	.61	.32
160-210 lb	.85	0	2.3	.63	.59	.31
210 lb -Transfer	.75	0	2.0	.62	.57	.31
Acclimation	.70	0	--	1.05	.96	.53
Gestation	.70	0	--	1.05	.96	.53
Lactation	1.30	5	--	1.08	.90	.49

Results and Discussion

Listed in Table 2 are the frequencies of sows used in the analysis for each event by treatment. Note that because gilt deliveries by treatment overlapped before a chromium-supplemented room was empty, some of the control gilts were fed chromium-supplemented feed. These pigs were taken off test. This resulted in approximately 50% fewer control animals compared to chromium-supplemented gilts.

The sow performance data are listed in Table 3. Note that an interaction (P<.04) between farm and treatment occurred for transfer age. Control gilts averaged 2.2 d older at transfer. The distribution for the control gilts is slightly skewed to the right. Further examination of the distributions by farm and treatment indicates that the interaction was due to a greater number of control gilts having a transfer age of more than 200 days in one farm. This difference was not observed in gilts fed chromium. This interaction probably was due to management decisions regarding the flow of gilts into the sow farm sites rather than dietary treatment.

The interaction between treatment and farm was not significant (P>.20) for age at first service. The mean age at first service was 9.3 days older (P<.01) for the chromium-supplemented gilts than for the control gilts. The age at first service was skewed to the right with a significant proportion of the gilts being greater than 300 d of age at first service. Very few of the control gilts had a first service age of greater than 300 d of age at either farm. Therefore, the mean difference was due to the skewing of the distribution of ages rather than the shifting of age at first service for all gilts. The greater number of gilts more than 300 d of age fed chromium could be due to one of three reasons: a management decision to voluntarily delay insemination of gilts at a greater rate for the chromium-supplemented gilts, failure to detect and inseminate gilts at a greater rate for the gilts fed chromium, or a biological effect of chromium supplementation. The interaction between dietary treatment and farm was significant (P<.04) for farrowing age. Although the interaction is significant, in contrast to age at first service, the distributions are generally similarly shaped.

The percentage of culls before first service was not different between treatments nor was first-service farrowing rate. However, the chromium-supplemented gilts had a numerically lower (5.2%) farrowing rate. No differences in gestation length occurred between chromium-supplemented and control sows. The distribution of gestation length appears to be normal for both treatments. This indicates that PRRS probably was not active during the study period.

Differences in total and live pigs born were not detected between chromium-supplemented and control gilts. In summary, this experiment failed to indicate a positive influence of chromium picolinate fed during development and gestation on reproductive and farrowing performance of parity 1 sows.

Table 2. Numbers of Sows by Event

	Treatment	
No. of Sows	Chromium	Control
Transferred	343	154
Culls before 1st service	14	6
First service	329	148
Farrowing	245	118

Table 3. Effect of Chromium Picolinate on Sow Performance

	Treatment		
Item	Chromium	Control	P-Value
Age, d			
Transfer[a]	178.7 ± .5	180.9 ± .7	-
First service[b]	235.1 ± 1.8	226.4 ± 2.7	.01
Farrowing[a]	348.2 ± 1.9	341.4 ± 2.8	-
Percentage			
Culls before 1st service	4.1	3.9	.97
1st service farrow rate	74.5	79.7	.21
Gestation length, d[b]	116.0 ± .1	116.1 ± .1	.88
Litter Size, no. of pigs			
Total born	10.8 ± .2	10.7 ± .3	.71
Live born	9.6 ± .2	9.5 ± .3	.78

[a]Transfer age and farrowing age by farm interaction (P<.04).

[b]First service age and gestation length by farm interaction (P>20).

EFFECTS OF INCREASED FEED INTAKE IN EARLY GESTATION ON SOW FARROWING PERFORMANCE AND OFFSPRING CARCASS CHARACTERISTICS[1]

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Summary

Three hundred and ninety-four PIC sows were used to determine the effects of increased feed intake during two critical stages of fetal development on farrowing performance and offspring carcass characteristics. Sows were fed 8 lb/d for one of three periods, d 10 to 30, d 30 to 50, or d 10 to 50 of gestation in comparison to a control level of 4 lb/d. Treatments did not affect the number of pigs farrowed. Sows fed 8 lb/d of complete diet from d 10 to 30 of gestation tended to have offspring with heavier hot carcass weight (P = .16) compared to offspring of other sows. Sows fed 8 lb/d of feed from d 30 to 50 produced offspring with greater backfat and decreased percentage lean than offspring of other sows. Effects observed in the carcass characteristics are inconsistent with previous findings, and more research is needed to determine the reason why these responses occurred.

(Key Words: Gestation, Feed Intake, Offspring.)

Introduction

Recent research indicates the possibility of manipulating maternal diet or other management practices during key stages of fetal development to realize more of the pig's genetic potential for lean growth. Treatments have varied from administration of exogenous somatatropin to increased feed intake. Unfortunately, results have varied even within treatment method. Whatever the treatment method, the improvements in pig performance are thought to be due to alterations in the development of fetal muscle fibers. These changes are important, because they set the upper limit of the pig's potential for lean deposition. Muscle fiber formation is such that the primary fibers (slow-twitch, red) develop a structural scaffolding for later formation of secondary muscle fibers (fast-twitch, white).

Research from Europe observed that increased feed intake from d 25 to 50 of gestation resulted in offspring that grew faster and more efficiently than control offspring. Also, previous research at Kansas State University reported that feeding either 8 lb/d of complete diet or 4 lb/d of complete diet with an additional 4 lb/d of ground corn from d 30 to 50 of gestation resulted in offspring that were heavier and leaner at slaughter than control offspring; however, the number of pigs born decreased. Although both experiments suggest that increasing feed intake for gestating sows during a window of d 25 to 50 of gestation will improve offspring performance, additional research is needed to determine if a different feeding period might have a greater influence on performance. Therefore, the objective of this experiment

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[4]Global Ventures, Inc., Pipestone, MN.

was to determine if increased feed intake during two key periods of early fetal development would alter the number of pigs born alive and/or carcass characteristics of the offspring.

Procedures

A total of 394 sows (PIC Cambrough sows × 326 boars) on a 3,000 sow commercial farm in southwest Minnesota was assigned randomly to one of four treatments based on the feed intake during different times of gestation. Sows received an increased amount of feed (8 lb/d) for one of three periods during gestation; d 10 to 30, 30 to 50, or 10 to 50. Control sows were fed 4 lb/d from d 0 to 100 gestation. The design covered the two critical periods identified for influencing muscle fiber number: embryonic (d 10 to 30), when germ layer differentiation leads to development of tissues and organs, and early fetal (d 30 to 50), just before secondary muscle differentiation. Sows were allotted to treatment at breeding and fed 4 lb/d of a complete gestation diet until d 10 (d 0 defined as the onset of estrus). All sows were provided 4 lb/d from d 50 to 100 and 6 lb/d from d 100 to 114 of gestation.

Maternal plasma samples were collected from 20 sows per treatment on d 50 of gestation, then subsampled and frozen for later determination of total and free insulin-like growth factor-I (IGF-I) and insulin. Sow farrowing data analyzed included numbers of pigs born alive, stillborn, and mummified per litter. After weaning, sows were monitored for days to estrus and subsequent fertility.

Pigs in a subsample of litters (25 per treatment) were weighed at birth. Within-litter variation of birth weight was evaluated using Levene's test, which tests the residual difference for each pig weight compared to litter average by analysis of variance.

Pigs were ear notched at birth according to the maternal treatment in gestation and then were standardized across treatments. At weaning, pigs were mixed within sex and moved to offsite nurseries. Pigs were moved to finishing buildings at 63 days of age. As pigs reached market weight (260 lb), they were sorted and marketed by treatment and sex for a total of eight different marketing groups (i.e., a load of barrows or gilts from each individual treatment). At the slaughter plant, experimental pigs were processed at the beginning of the day to decrease the potential variation in Fat-O-Meter™ measurements. Individual carcass measurements were obtained on 1,835 pigs.

Table 1. Gestation Diet Composition[a]

Ingredient	Percent
Corn	74.9
Soybean meal (46.5%)	15.6
Alfalfa meal	5.0
Other vitamin and trace mineral additions	4.5
Total	100.0

[a]Formulated to contain .7% lysine, 1.0% Ca, and .90% P.

Results and Discussion

The number of pigs born was similar for sows provided increased feed during either treatment phase of gestation and control sows. Chance differences were observed in age of the sows used in this experiment (with sows fed 8 lb/d in gestation tending to be older, P<.10; Table 2); therefore, parity was used as a covariate to equalize differences. In a previous experiment, a decrease in the number of pigs born alive was observed when sows were fed 8 lb/d of complete feed from d 30 to 50 of gestation; however, this was not observed in the current experiment. No differences (P>.10) occurred in the number of pigs born stillborn or mummified.

No differences were observed (P>.10; Table 3) in either pig or litter birth weight or pig birth weight variation.

Free IGF-I (not bound by binding proteins) was elevated (P<.05; Table 4) on d 50 in plasma of sows fed increased feed from d 30 to 50 and d 10 to 50 of gestation but not d 10 to 30; however, sows fed 8 lb/d from d 10 to 30 had been fed 4 lb/d for the previous

20 days. Total IGF-I was not different for the various treatments, nor was the percentage of IGF-I that was in the bound form (approx. 98% bound). Insulin was elevated (P<.01) on d 50 of gestation, and sows fed 8 lb/d from d 30 to 50 had the highest values.

Pigs from sows fed increased feed from d 30 to 50 of gestation were less lean and had a higher amount of backfat at slaughter. A trend (P = .16) existed for increased hot carcass weight in offspring from sows fed increased feed from either d 10 to 30 or d 30 to 50 of gestation. Results of this experiment suggest that feeding sows 8 lb/d from d 10 to 30 of gestation tends to increase hot carcass weight of barrow offspring. However, in contrast to previous research, we observed that increased feed from d 30 to 50 of gestation decreased (P<.05; Table 5) percentage lean and fat-free lean index and increased (P<.05) backfat depth of offspring. Feeding sows 8 lb/d of complete diet from d 10 to 50 resulted in offspring with carcass characteristics similar (P>.10) to those of control offspring.

The analysis of subsequent farrowing rate showed no differences from feed intake level during gestation. Also, no differences in the number of pigs born, born alive, stillborn, or mummified per litter were observed when sows were fed increased feed in the previous gestation compared to control sows. A increase in the length to return to estrus was observed (P<.05; Table 6) when sows were fed 8 lb/d from d 10 to 50 of gestation.

Previously, we observed that sows fed 8 lb/d from d 30 to 50 of gestation produced offspring that were leaner and heavier at slaughter than control offspring. However, this was not observed in the current experiment. In fact, the response was just the opposite, with increased fat depth and a lower percentage lean observed for offspring from sows fed 8 lb/d from d 30 to 50 of gestation. Although offspring from sows with high feed intake from d 30 to 50 had less lean, the increase in hot carcass weight was similar to that in the previous experiment. Increased hot carcass weight of the offspring may be consistent with work from Europe, where an improvement in ADG was observed for offspring of sows provided additional feed during gestation. Although no advantage in percentage lean was observed in the offspring of sows with increased feed intake from d 10 to 50 of gestation, percentage lean was improved in offspring from sows fed 8 lb/d from d 10 to 30 of gestation.

Several differences exist between previous experiments and the current study. Differences in parity, weight of offspring at slaughter, and overall leanness of the offspring may have important effects. Sows in the current experiment were older, and hot carcass weight was lighter (approximately 20 lbs). Because the offspring in the current experiment were considerably lighter than the animals in the first experiment, they were leaner and this might have limited the treatments' abilities to enhance lean growth. Because of the unknown effects of parity and marketing age/weight, future research should address these questions.

Although a window of treatment at approximately d 10 to 30 of gestation may exist when increased feed intake would lead to improved muscle development of the fetal pig, more research is needed to assure the repeatability of this response.

Table 2. Effects of Increased Feed Intake during Gestation on Sow and Litter Performance

		8 lb/d of Feed from				
Item	Control	D 10-30	D 30-50	D 10-50	SEM	P<
Number of sows	104	97	95	98		
Avg. parity	3.52[b]	4.41[c]	3.87[b]	3.69[b]	.26	.07
No. pigs born[a]	10.28	10.59	9.99	9.81	.60	.48
No. pigs born alive[a]	8.78	9.16	8.53	8.08	.60	.23
No. pigs born stillborn[a]	.92	.90	.93	1.08	.16	.68
No. pigs born mummified[a]	.58	.54	.52	.65	.23	.93

[a]Means were adjusted for parity by covariate analysis.
[b,c]Means differ P < .05.

Table 3. Effects of Increased Feed Intake during Gestation on Litter Birth Weight and Pig Weight Variation within the Litter

		8 lb/d of Feed from				
Item	Control	D 10-30	D 30-50	D 10-50	SEM	P <
No. litters	17	19	14	21		
No. pigs per litter	8.94	9.26	9.29	9.71	.67	.82
Avg. pig birth weight, lb	3.07	3.43	3.46	3.20	.18	.32
Avg. litter birth weight, lb	30.85	32.57	32.80	31.58	1.90	.86
Residual variation in birth weight, lb[a]	.45	.44	.63	.48	.07	.16

[a]Lower values would indicate less variation of weight within the litter.

Table 4. Effects of Increased Feed Intake during Gestation on Blood Metabolites[a]

		8 lb/d of Feed from				
Item	Control	D 10-30	D 30-50	D 10-50	SEM	P <
No. sows	19	21	17	18		
Total IGF-I, ng/ml	59.5[a]	50.1[a]	74.9[b]	67.5[a]	8.85	.20
Free IGF-I, ng/ml	1.31[ac]	1.18[b]	1.62[c]	2.05[d]	.24	.01
Percent IGF-I bound, %	98.2	99.3	98.5	98.1	.57	.34
Insulin, ng/ml	.78[ab]	.63[b]	1.04[c]	.84[ac]	.09	.01

[a]Means differ at P<.10.

Table 5. Effect of Increased Feed Intake during Gestation on Offspring Carcass Performance

		8 lb/d of Feed from				
Item	Control	D 10-30	D 30-50	D 10–50	SEM	P <
Gilt Offspring	188	294	237	244		
Age, d	186.3	186.2	186.8	186.9	.44	.40
Hot carcass weight, lb[c]	184.4	186.1	187.4	183.5	1.56	.16
Backfat, mm [d]	12.85[a]	13.01[a]	13.79[b]	13.21[a]	.24	.01
Percentage lean, %[d,e]	57.86[a]	57.79[a]	57.30[b]	57.67[ab]	.16	.01
Loin depth, mm[d]	57.87[a]	58.33[a]	57.62[a]	57.86[a]	.48	.03
Fat free lean index[d,e]	51.83[a]	51.75[a]	51.37[b]	51.66[a]	.11	.01
Barrow Offspring	198	246	228	200		
Age, d	186.5	186.8	187.0	187.0	.43	.40
Hot carcass weight, lb[c]	185.1	188.1	184.4	184.9	1.52	.16
Backfat, mm[d]	16.67[a]	16.33[a]	17.77[b]	16.77[a]	.23	.01
Percentage lean, %[d,e]	55.29[a]	55.60[a]	54.50[b]	55.28[a]	.16	.01
Loin depth, mm[d]	55.32[a]	55.80[a]	53.99[b]	55.44[a]	.47	.03
Fat free lean index[d,e]	49.99[a]	50.15[a]	49.45[b]	49.94[a]	.11	.01

[a,b]Means differ at P<.05.

[c]Means were adjusted for age at market by covariate analysis.

[d]Means were adjusted for hot carcass weight by covariate analysis.

[e]Represent calculated plant values.

Table 6. Effects of Increased Feed Intake during Gestation on Sows' Subsequent Farrowing Performance[a]

		8 lb/d of Feed from				
Item	Control	D 10-30	D 30-50	D 10-50	SEM	P <
Number of sows	66	57	56	52		
Return to estrus, d	5.86[b]	5.76[b]	5.74[b]	7.76[c]	.84	.04
Farrowing rate, %	85.6	83.8	89.5	79.0	7.61	.59
No. pigs born	9.2	10.06	10.26	9.52	.67	.37
No. pigs born alive	8.05	8.93	8.72	8.73	.61	.48
No. pigs born stillborn	.73	.70	.95	.62	.18	.35
No. pigs born mummified	.42	.44	.59	.17	.23	.39

[a]Means were adjusted for parity by covariate analysis.

[b,c]Means differ P < .05.

EFFECTS OF SPRAY-DRIED ANIMAL PLASMA SOURCE ON WEANLING PIG PERFORMANCE[1]

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Summary

Three studies were conducted to evaluate the effects of different spray-dried animal plasma (SDAP) sources on weanling pig performance. For this study, different sources of SDAP were obtained from each of the four largest marketers. In each experiment, a different lot of each of the four plasma sources was used. Pigs were fed either a control diet or one of four diets containing different plasma sources added at 5.0 % of the total diet. The results of these experiments suggest that larger differences occur between lots or batches of SDAP then between sources of SDAP, when weanling pig performance is used as the response criterion. More research must be done to determine the factors responsible for the differences between batches of SDAP.

(Key Words: Starter Pigs, Spray-Dried Animal Plasma, Performance.)

Introduction

Spray-dried animal plasma has become an important ingredient in starter diets for early-weaned pigs, because studies have shown that it increases ADG and ADFI. Different sources of SDAP are now available for use in commercial diets. Producers and nutritionists frequently ask which plasma source to use. To date, relatively few trials have been conducted comparing different lots or sources of SDAP. Therefore, the objective of these experiments was to evaluate different batches and sources of SDAP and determine if differences occurred when starter pig performance was used as the response criterion.

Procedures

In all experiments, pigs (PIC) were blocked by initial weight, equalized for sex, and allotted randomly to one of five dietary treatments. The trials were divided into two phases, with the experimental diets fed from d 0 to 14 after weaning. The control pigs were fed a corn-soybean meal-based diet in a meal form containing 15% dried whey (Table 1). Other experimental diets contained different sources of SDAP replacing soybean meal in the control diet on an equal lysine basis. Diets contained no added medications or growth-promotional zinc oxide. From d 14 to 28 after weaning, a common corn-soybean meal diet containing no SDAP was fed in a meal form (Table 1).

Pigs were weighed and feed disappearance was determined on d 0, 7, 14, 21, and 28 after weaning to calculate ADG, ADFI, and F/G. Data were analyzed in a randomized complete block design with pen as the experimental unit.

In Exp. 1, 190 early-weaned pigs (averaging 17 d of age and 10.1 lb) were housed at the Kansas State University Segregated Early-Weaning facility. This nursery contained 4×4 ft pens with a self-feeder and one nipple waterer in each pen to provide ad

[1]The authors thank Henry's LTD, Longford, KS for providing the pigs used in Exps. 1 and 3.
[2]Northeast Area Extension Office, Manhattan, KS.
[3]Food Animal Health and Management Center.

libitum access to feed and water. There were four or five pigs per pen, and pens within a replication had the same number of pigs per pen. Each treatment had eight replications. In Exp. 2, 200 weanling pigs (averaging 21 d of age and 13.4 lb) were housed at the Kansas State University Swine Teaching and Research Center in 5 × 5 ft pens and were provided ad libitum access to feed and water. There were eight replications per treatment with six pigs per pen. In Exp. 3, 170 weanling pigs (averaging 18 d of age and 12.7 lb) were housed in the same facilities as Exp. 1. There were seven replications per treatment and four or five pigs per pen.

Results and Discussion

Experiment 1. From d 0 to 7 after weaning, all pigs fed SDAP (regardless of source) had greater (P<.01) ADG and ADFI than pigs fed the control diet (Table 2). Pigs fed diets containing SDAP sources 3 and 4 had higher (P< .02) ADG than pigs fed sources 1 and 2. Pigs fed SDAP source 3 also had greater feed intake (P<.01) than pigs fed diets containing plasma sources 1 and 2, and pigs fed diets containing plasma source 4 had intermediate ADFI. From d 0 to 14 after weaning, all pigs fed SDAP had (P<.03) increased ADG and ADFI compared to the control pigs. Pigs fed SDAP source 4 had greater ADG (P<.02) and ADFI (P<.01) compared to pigs fed the control diet, and pigs fed sources 1, 2, and 3 had intermediate ADG and ADFI. No differences were observed in pig performance from d 14 to 28, and overall performance was not affected by the diet fed from d 0 to 14.

Experiment 2. From d 0 to 7 after weaning, pigs fed diets containing SDAP had improved (P< .04) ADG, ADFI, and F/G compared with pigs fed the control diet (Table 3). Pigs fed the diet containing SDAP source 2 also had greater ADFI (P< .05) than pigs fed the control diet. Feed efficiency for pigs fed SDAP sources 1, 2, and, 4 was better (P< .02) than that of pigs fed the control diet. From d 0 to 14, pigs fed the control diet had increased ADG compared to pigs fed diets containing plasma sources 2 and 3, and pigs fed plasma sources 1 and 4 had intermediate gains. Pigs fed the diet containing plasma source 2 also had decreased F/G compared to pigs fed the control diet, and pigs fed diets containing plasma sources 1, 3, and 4 had intermediate F/G. No differences were observed in pig performance from d 14 to 28. From d 0 to 28, performance was not affected by the diet fed from d 0 to 14.

Experiment 3. From d 0 to 7 after weaning, pigs fed SDAP had improved (P<.02) ADG, ADFI, and F/G compared with pigs fed the control diet (Table 4). Pigs fed SDAP from sources 1 and 4, had greater (P<.01) ADG and ADFI than pigs fed the control diet, and pigs fed plasma sources 2 and 3 had intermediate ADG and ADFI. From d 0 to 14, pigs fed SDAP sources 1 and 4 had improved ADG compared to pigs fed the control diet, and pigs fed plasma sources 2 and 3 had intermediate gains. Average daily feed intake was greatest for pigs fed plasma sources 1, 2, and 4, and pigs fed plasma from source 3 had intakes similar to those of pigs fed the control diet. From d 0 to 14, no differences occurred in feed efficiency. No differences were observed in pig performance from d 14 to 28, and overall growth performance was not affected by the diet fed from d 0 to 14.

These results confirm earlier research demonstrating increased pig growth performance when spray-dried animal plasma is added to starter diets. However, the results of these experiments also suggest that pig growth performance from d 0 to 7 after weaning may be affected by variation within sources of SDAP used in the diet. These results also suggest that greater differences occur between lots or batches of spray-dried animal plasma from the same supplier than between sources from the different suppliers. None of the plasma sources tested consistently provided the best growth performance. We have begun further research to try to determine the factors responsible for the differences observed between lots of SDAP.

Table 1. Compositions of Experimental Diets

	Day 0 to 14[a]		
Ingredient, %	Control	5% SDAP	Day 14 to 28[b]
Corn	44.64	51.47	53.79
Soybean meal (46.5% C.P.)	34.04	22.18	25.86
Spray-dried animal plasma	--	5.00	--
Dried whey	15.00	15.00	10.00
Soy oil	3.00	3.00	3.00
Monocalcium P (21% P)	1.40	1.32	1.89
Limestone	.95	1.00	0.81
Salt	.30	.30	0.25
Vitamin premix	.25	.25	0.25
L-lysine HCl	.15	.15	0.15
Trace mineral	.15	.15	0.15
DL-methionine	.10	.13	0.10
Zinc oxide	--	--	0.25
Medication[c]	--	--	1.00
Spray-dried blood cells	--	--	2.50

[a]Formulated to contain 1.4% lysine, .90% Ca, and .80% P.
[b]Fed in meal form to all pigs and formulated to contain 1.35% lysine, .85% Ca, and .75% P.
[c]Provided 50 g/ton carbadox.

Table 2. Effects of Plasma Source on Weanling Pig Growth Performance (Exp. 1)[a]

		Plasma Source				
Item	Control	1	2	3	4	SEM
Day 0 to 7						
ADG[b], lb	.04[c]	.17[d]	.20[d]	.28[e]	.26[e]	.031
ADFI[b], lb	.17[c]	.26[d]	.30[d]	.37[e]	.34d[de]	.026
F/G	2.04	1.78	1.61	1.37	1.46	4.25
Day 0 to 14						
ADG[b], lb	.28[d]	.36[cd]	.33[cd]	.34[cd]	.38[c]	.026
ADFI[b], lb	.39[d]	.47[cd]	.47[cd]	.47[cd]	.54c	.029
F/G	1.44	1.34	1.41	1.40	1.45	.065
Day 14 to 27						
ADG, lb	.79	.94	.97	.97	.91	.048
ADFI, lb	1.54	1.60	1.55	1.40	1.54	.070
F/G	1.53	1.66	1.61	1.44	1.66	.080
Day 0 to 27						
ADG[b], lb	.53	.64	.64	.64	.64	.033
ADFI, lb	.94	1.01	.99	.92	1.02	.042
F/G	1.50	1.51	1.55	1.43	1.59	.058

[a]A total of 190 weanling pigs initially 10.1 lb and 17 days of age.
[b]Control vs. the mean of SDAP source 1, 2, 3 and 4 (P>.05).
[cde]Means in the same row with different superscripts differ (P<.05).

Table 3. Effects of Plasma Source on Weanling Pig Growth Performance (Exp. 2)[a]

		Plasma Source				
Item	Control	1	2	3	4	SEM
Day 0 to 7						
ADG[b], lb	.28[c]	.43[d]	.42[d]	.36[d]	.42[d]	.028
ADFI[b], lb	.49[c]	.60[cd]	.62[d]	.58[cd]	.55[cd]	.038
F/G[b]	1.90[c]	1.42[d]	1.53[d]	1.60[cd]	1.35[d]	.110
Day 0 to 14						
ADG, lb	.54[c]	.51[cd]	.45[d]	.45[d]	.47[cd]	.026
ADFI, lb	.75	.76	.73	.69	.69	.033
F/G	1.40[c]	1.50[cd]	1.65[d]	1.54[cd]	1.50[cd]	.058
Day 14 to 28						
ADG, lb	1.28	1.27	1.27	1.32	1.24	.032
ADFI, lb	1.85	1.85	1.83	1.88	1.82	.040
F/G	1.45	1.46	1.44	1.43	1.47	.032
Day 0 to 28						
ADG, lb	.91	.89	.86	.88	.86	.024
ADFI, lb	1.30	1.31	1.28	1.28	1.25	.032
F/G	1.43	1.47	1.49	1.45	1.47	.031

[a]A total of 200 weanling pigs initially 13.4 lb and 21 days of age.
[b]Control vs. the mean of SDAP source 1, 2, 3 and 4 (P<.05).
[cde]Means in the same row with different superscripts differ (P<.05).

Table 4. Effects of Plasma Source on Weanling Pig Growth Performance (Exp. 3)[a]

		Plasma Source				
Item	Control	1	2	3	4	SEM
Day 0 to 7						
ADG[b], lb	.09[c]	.24[d]	.17[cd]	.14[cd]	.24[d]	.039
ADFI[b], lb	.22[c]	.33[de]	.30[cde]	.25[cd]	.35[e]	.032
F/G[b]	5.09[c]	1.39[d]	2.11[cd]	2.10[cd]	1.88[d]	1.22
Day 0 to 14						
ADG, lb	.35[c]	.48[d]	.41[cd]	.35[c]	.44[cd]	.043
ADFI, lb	.51[c]	.64[d]	.57[cd]	.51[c]	.63[d]	.042
F/G	1.46	1.34	1.47	1.43	1.47	.091
Day 14 to 28						
ADG, lb	1.17	1.16	1.14	1.11	1.15	.066
ADFI, lb	1.63	1.62	1.69	1.58	1.62	.056
F/G	1.40	1.39	1.58	1.43	1.41	.096
Day 0 to 28						
ADG, lb	.76	.82	.77	.74	.80	.044
ADFI, lb	1.07	1.13	1.13	1.04	1.12	.043
F/G	1.41	1.38	1.50	1.41	1.42	.053

[a]A total of 170 weanling pigs (initially 12.8 lb) with four or five pigs per pen and seven pens per treatment.
[b]Control vs. the mean of SDAP sources 1, 2, 3, and 4 (P <.05).
[c,d,e]Means in same row with different superscripts differ (P<.05).

EFFECTS OF DIFFERENT ZINC OXIDE SOURCES ON WEANLING PIG GROWTH PERFORMANCE[1]

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Summary

A total of 192 pigs (initially 13.6 lb and 18 d of age) were used in a 27-d growth assay to determine the effects of different ZnO sources on weanling pig growth performance. The four experimental treatments consisted of a control diet or three diets containing Zn from ZnO from one of three different sources. For the entire trial, no differences occurred in growth performance of pigs fed the different ZnO sources; however, all sources increased ADG and ADFI compared to pigs fed the control diet. Economics and ingredient availability should dictate which ZnO source to use in weanling pig diets to promote growth.

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

Introduction

Previous trials at Kansas State University and other universities have demonstrated the beneficial effects of adding high levels of dietary ZnO (3,000 ppm of Zn) on growth performance of weanling pigs. However, not all trials have demonstrated the same magnitude of response, and others have observed no response at all. Questions remain as to whether the inconsistencies observed in growth performance were results of differences in the ZnO sources used in the trials. Different techniques can be used to manufacture and/or process ZnO, and consequently, the quality of the resulting ZnO will vary greatly. Recent research from the University of Illinois has shown that the bioavailability of Zn from different ZnO sources differs considerably (39.5 to 95.5%) when added at low levels in diets fed to Zn-depleted chicks. However, the influence of pharmacological levels (20 to 30 × NRC requirement estimate) of Zn from different ZnO sources on weanling pig growth performance has not been tested. Therefore, the objective of this trial was to determine the effects of high levels of Zn from one of three different commercially available ZnO sources on weanling pig growth performance.

Procedures

A total of 192 weanling pigs (initially 13.6 lb and 18 d of age; PIC) was used in a 27 d growth assay. Pigs were blocked by initial weight and allotted randomly to each of four dietary treatments. Each treatment had six replications (pens) and eight pigs per pen.

The four experimental treatments consisted of a basal diet with no additional Zn or the basal diet with added ZnO from one of three different commercially available sources. Added Zn levels were 3,000 ppm of Zn from d 0 to 14 and 2,000 ppm of Zn from d 14 to 27. All diets contained 165 ppm of Zn from ZnO provided by the trace mineral premix. The experimental diets were fed in meal form and contained no feed grade medication. Diets (Table 1) were fed in three phases (d 0 to 7, 7 to 14, and 14 to 27) with

[1]The authors thank Eichman Brothers, St. George, KS, for the use of facilities and pigs for this experiment.

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

decreasing nutrient concentrations and specialty protein sources in each subsequent phase. The ZnO replaced cornstarch in the basal diet to provide the experimental treatments. Complete trace mineral profiles were determined for each Zn source (Table 2). The sources varied considerably in their respective trace mineral profiles; however, diets were not equalized based on mineral concentrations other than Zn from the sources.

Pigs were housed in an environmentally controlled nursery in 5 × 5 ft pens on a commercial farm in northeast Kansas. Pens contained one self-feeder and two nipple waters to provide ad libitum access to feed and water. Pigs were weighed and feed disappearance was determined on d 0, 7, 14, 21, and 27 to determine ADG, ADFI, and F/G.

Data were analyzed in a randomized complete block design using the general linear model (GLM) of SAS with pen as the experimental unit. Orthogonal contrasts were used to compare ZnO sources and to compare the control treatment to treatments containing added ZnO.

Results and Discussion

Analysis of the Zn sources resulted in a wide variation in the concentration of other trace minerals found in the ZnO sources (Table 2). These differences exist because of the different procedures used to manufacture the sources. One Zn source was manufactured by the Waells process, which is known to produce some of the purest feed-grade ZnO available in the United States. Another of the sources is actually a by-product of the iron industry and contains Zn that has been shown to be bound to iron as a relatively unavailable zinc-ferrite complex. The third ZnO source is a product sold as a blend of other commercially available ZnO sources.

For the entire experiment, all three ZnO sources had similar (P>.28; Table 3.) effects on growth performance of the pigs. From d 0 to 7, pigs fed diets containing high levels of ZnO tended to have greater (P<.09) ADG compared to pigs fed the control. Pigs fed high levels of ZnO had similar (P>.59) ADFI but improved (P<.04) F/G compared to pigs fed the control.

From d 7 to 14 and d 0 to 14, ADG and ADFI were increased (P< .02) when high levels of ZnO was added to the diets. Feed to gain ratio was not influenced (P>.32) by high levels of ZnO from d 7 to 14; however, when d 0 to 7 and d 7 to 14 data were combined, F/G was improved (P<.04) by adding high levels of ZnO to the diets.

From d 14 to 27 and 0 to 27, adding ZnO to the diets increased (P<.002) ADG and ADFI compared to control diets. Feed to gain ratio was not affected (P>.29) by adding ZnO to diets from d 14 to 27, although for the overall data, d 0 to 27, F/G tended to be improved (P<.09) for pigs fed diets containing high levels of ZnO compared to pigs fed the control diet.

These results are similar to those of some experiments conducted at Kansas State University showing a beneficial response in growth performance of pigs fed pharmacological levels of ZnO. Possible explanations of why other experiments have not shown a similar response include differences in initial weight, age, genetics, or health status of the pigs. The results of this experiment suggest that 3,000 ppm of Zn from ZnO should be added from d 0 to 14 after weaning and 2,000 ppm of Zn added from d 14 to 27 to improve pig growth performance. These data also suggest that no differences occur in growth performance of pigs fed Zn from different ZnO sources when added at growth promotional levels (30 × NRC requirement estimate); however, differences might exist if sources were added at lower concentrations. Price and availability of the different sources should help dictate which source to use for growth promotion.

Table 1. Diet Composition (As-Fed Basis)

Ingredient, %	Day 0 to 7	Day 7 to 14	Day 14 to 27
Corn	38.81	45.78	52.07
Dried whey	25.00	20.00	10.00
Soybean meal (46.5% CP)	12.18	21.30	28.50
Spray-dried animal plasma	6.75	2.50	-
Select menhaden fish meal	6.00	2.50	-
Lactose	5.00	-	-
Soy oil	2.00	2.00	3.00
Spray-dried blood meal	1.75	2.50	2.50
Monocalcium phosphate	.69	1.26	1.59
Limestone	.50	.76	.99
Cornstarch[a]	.40	.40	.40
Salt	.25	.30	.30
Vitamin premix	.25	.25	.25
L-Lysine HCL	.15	.15	.15
Trace mineral premix[b]	.15	.15	.15
DL-Methionine	.12	.15	.10
Total	100.00	100.00	100.00
Calculated analysis, %			
Lysine	1.70	1.55	1.40
Methionine	.48	.44	.39
Ca	.90	.90	.85
P	.80	.80	.75

[a]Zinc oxide replaced cornstarch to provide the experimental treatments.
[b]Provided per ton of complete feed: 36 g Mn; 150 g Fe; 150 g Zn from ZnO; 15 g Cu; 270 mg I; and 270 mg Se.

Table 2. Analyzed Trace Mineral Profiles of Zinc Oxide Sources[a]

	ZnO Source		
Mineral	1	2	3
Ca, %	2.31	.14	2.03
Cu, ppm	305.4	94	352.3
Fe, %	1.74	9.90	2.68
K, %	.08	.03	.13
Mg, %	.24	.15	.17
Mn, ppm	2,738	984	1,554
Na, %	.39	.08	.51
P, %	<.01	.02	.01
S, %	.13	.32	.18
Zn, %	73.4	69.9	74.5

[a]Values are the means of two analyses of each source reported on an as-fed basis.

Table 3. Influence of Different Zinc Oxide Sources on Weanling Pig Growth Performance[a]

		ZnO Source				Contrasts, $P <$			
Item	Control	1	2	3	SEM	Control vs 1,2,3	1 vs 2	1 vs 3	2 vs 3
Day 0 to 7									
ADG, lb	.31	.38	.38	.38	.033	.09	.91	.98	.89
ADFI, lb	.42	.43	.46	.43	.025	.59	.38	.97	.40
F/G	1.40	1.14	1.25	1.11	.091	.04	.50	.80	.28
Day 7 to 14									
ADG, lb	.68	.81	.85	.82	.049	.02	.61	.91	.70
ADFI, lb	.84	.98	.96	.96	.032	.004	.72	.62	.89
F/G	1.25	1.23	1.15	1.19	.055	.32	.29	.58	.61
Day 0 to 14									
ADG, lb	.49	.60	.61	.60	.030	.007	.73	.92	.81
ADFI, lb	.63	.70	.71	.69	.023	.02	.82	.74	.57
F/G	1.28	1.19	1.16	1.16	.042	.04	.63	.59	.96
Day 14 to 27									
ADG, lb	1.03	1.25	1.25	1.25	.050	.0018	.94	.94	.99
ADFI, lb	1.47	1.73	1.69	1.69	.052	.0012	.60	.62	.98
F/G	1.43	1.39	1.40	1.35	.048	.29	.63	.57	.93
Day 0 to 27									
ADG, lb	.75	.91	.92	.91	.033	.0007	.82	.92	.91
ADFI, lb	1.03	1.20	1.18	1.17	.028	.0003	.72	.57	.84
F/G	1.38	1.32	1.29	1.28	.037	.09	.56	.49	.91

[a]Values represent the means of 192 pigs (initially 13.6 lb and 18 d of age); eight pigs per pen and six pens per treatment.

INFLUENCE OF ADDED ZINC FROM ZINC SULFATE ON WEANLING PIG GROWTH PERFORMANCE AND PLASMA ZINC CONCENTRATION[1]

J. C. Woodworth, M. D. Tokach[2], J. L. Nelssen, R. D. Goodband, P. R. O'Quinn, and J. T. Sawyer

Summary

A total of 288 weanling pigs (13.4 lb and 18 d of age) was used in a 27 d growth assay to determine the effects of adding Zn from $ZnSO_4$ or ZnO on growth performance. Pigs were allotted to one of eight dietary treatments consisting of a control diet; diets containing one of six concentrations of Zn from $ZnSO_4$ (500, 1,000, 1,500, 2,000, 2,500, or 3,000 ppm); and a diet containing 3,000 ppm of Zn from ZnO. Increasing Zn from $ZnSO_4$ linearly improved ADG and F/G from d 9 to 19; however, adding $ZnSO_4$ to the diet decreased ADG from d 19 to 33. Thus, pigs fed diets containing $ZnSO_4$ or 3,000 ppm of Zn from ZnO had similar growth performance compared to pigs fed the control diet for the overall trial. In conclusion, no benefit was observed for the overall trial from adding increasing concentrations of Zn from $ZnSO_4$ or 3,000 ppm of Zn from ZnO.

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

Introduction

The benefits to growth performance from adding high (3,000 ppm) levels of Zn from ZnO are well known. However, similar results have not been reported from feeding the same levels of other Zn sources, such as $ZnSO_4$. Previous research also has shown that the availability of Zn from ZnO can be as much as 50% lower than the availability of Zn from $ZnSO_4$. Thus, one possible explanation for why high levels of Zn from $ZnSO_4$ do not support added growth performance similar to high levels of Zn from ZnO is because the pigs fed high levels of $ZnSO_4$ might have a borderline Zn toxicity that impairs growth performance.

Other research conducted at the University of Illinois has concluded that plasma Zn concentrations of 1.5 to 3.0 mg/L were correlated with increased growth performance of pigs. In a previous trial conducted at Kansas State University, pigs fed 3,000 ppm of Zn from ZnO had higher ADG and ADFI compared to those fed increasing concentrations (100 to 500 ppm) of Zn from $ZnSO_4$. However, pigs fed the diet containing $ZnSO_4$ did have improved growth performance compared to pigs fed only 165 ppm of Zn from ZnO in the trace mineral premix. Only pigs fed the diet containing 3,000 ppm of Zn from ZnO had plasma Zn concentrations above 1.5 mg/L. The current trial was designed to determine if feeding lower levels of a more available Zn source ($ZnSO_4$) would elicit similar growth performance as feeding high levels of ZnO by measuring growth and correlating it to plasma Zn concentrations.

Procedures

A total of 288 weanling pigs (initially 13.4 lb and 18 d of age; PIC) was blocked by initial weight and allotted randomly to each of eight dietary treatments in a 33 d growth

[1]Appreciation is expressed to Henry's Ltd. for supplying the pigs for this experiment and to Colin Bradley of the London Health Sciences Centre, London, Ontario, Canada for conducting the plasma Zn analysis.

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

assay. Each treatment had eight replications (pens) per treatment and four or five pigs per pen.

All experimental diets (Table 1) were fed in meal form, in four phases (d 0 to 5, 5 to 9, 9 to 19, and 19 to 33) with decreasing specialty protein sources and nutrient concentrations in each subsequent phase. The eight experimental diets consisted of a control diet, six diets containing increasing (500, 1,000, 1,500, 2,000, 2,500, or 3,000 ppm) Zn from $ZnSO_4$; and a positive control diet containing 3,000 ppm of Zn from ZnO. All diets contained 165 ppm of Zn from ZnO provided by the trace mineral premix and were formulated with no feed grade medication. Pigs were fed the same experimental Zn concentrations throughout the 33 d study. Zinc sulfate and ZnO replaced cornstarch in the control diet to form the experimental treatments.

Pigs were housed in the Kansas State University segregated early-weaning facility. Each pen was 4 × 4 ft and contained one nipple waterer and one self-feeder to provide ad libitum access to feed and water. Initial temperature of the nursery was 90°F and was lowered approximately 3°F each week thereafter.

Pigs were weighed and feed disappearance was determined at weaning and on d 5, 9, 19, 26, and 33 after to calculate ADG, ADFI, and F/G. Two pigs per pen were selected randomly and bled on d 9, 19, and 33 to determine plasma Zn concentration. Samples were centrifuged, and the plasma from the two pigs in each pen was pooled for analysis.

Data were analyzed as a randomized complete block design with pen as the experimental unit. Linear, quadratic, and cubic polynomials were used to evaluate increasing concentrations of $ZnSO_4$. Orthogonal contrasts were used to investigate the mean differences between the basal control diet, the mean of diets containing $ZnSO_4$, and the positive control diet.

Results and Discussion

From d 0 to 9, ADG tended to be lower ($P<.09$) and ADFI was lower ($P<.006$) for the mean of pigs fed diets containing $ZnSO_4$ compared to pigs fed the control diet or the diet containing 3,000 ppm of Zn from ZnO. Feed to gain ratio tended to be poorer ($P<.09$) for pigs fed the positive control diet compared to the mean of pigs fed diets containing $ZnSO_4$. Average daily gain, ADFI, and F/G were similar ($P>.10$) for pigs fed the control diet compared to pigs fed 3,000 ppm of Zn from ZnO. Increasing the concentration of $ZnSO_4$ did not affect ($P>.10$) ADG, ADFI, or F/G.

From d 9 to 19, ADG was similar ($P>.10$) for pigs fed the control diet, the diet containing 3,000 ppm of Zn from ZnO, and the mean of pigs fed diets containing $ZnSO_4$. Average daily gain increased (linear, $P<.05$) for pigs fed diets containing increasing concentrations of $ZnSO_4$. Average daily feed intake tended to be greater ($P<.09$) for pigs fed the positive control diet compared to the mean of pigs fed diets containing $ZnSO_4$, but was similar ($P>.10$) to that of pigs fed the control diet. Feed to gain ratio was similar ($P>.51$) for pigs fed the control diet compared to pigs fed diets containing 3,000 ppm of Zn from ZnO, but pigs fed either diet had poorer ($P<.06$) F/G compared to the mean of pigs fed diets containing $ZnSO_4$. Average daily feed intake and F/G tended to improve ($P<.10$) when pigs were fed diets containing increasing concentrations of $ZnSO_4$.

From d 19 to 33, pigs fed the control diet had greater ($P<.01$) ADG compared to the mean of pigs fed diets containing $ZnSO_4$ and tended to have greater ($P<.08$) ADG compared to pigs fed diets containing 3,000 ppm of Zn from ZnO. Average daily feed intake tended to be greater ($P<.10$) for pigs fed the control diet compared to the mean of pigs fed diets containing $ZnSO_4$. Pigs fed the control diet, diets containing 3,000 ppm of Zn from ZnO, or the mean of pigs fed diets containing $ZnSO_4$ had similar ($P<.10$) F/G. Increasing the concentration of $ZnSO_4$ did not affect

(P>.10) ADG or ADFI; however, F/G decreased then increased then decreased (cubic, P<.05) with increasing $ZnSO_4$, and pigs fed 1,000 ppm of Zn from $ZnSO_4$ had the best F/G.

Overall, from d 0 to 33, ADG was not influenced (P>.10) by Zn source or level. Average daily feed intake tended to be greater (P<.08) for pigs fed the control diet compared to the mean of pigs fed diets containing $ZnSO_4$. Pigs fed the diet containing 3,000 ppm of Zn from ZnO had similar (P >.10) ADFI compared to either the pigs fed the control diet or the mean of pigs fed diets containing $ZnSO_4$. Feed to gain ratio was similar (P > .10) for pigs fed the control diet, the mean of pigs fed diets containing $ZnSO_4$, and pigs fed the diet containing 3,000 ppm of Zn from ZnO. Similar to d 19 to 33, increasing the concentration of Zn from $ZnSO_4$ decreased then increased then decreased (cubic, P<.05) F/G, and pigs fed the diets containing 1,000 or 3,000 ppm of Zn from $ZnSO_4$ had the best F/G.

Plasma Zn concentrations on d 9 and 19 were lowest (P<.0001) for pigs fed the control diet and highest (P<.0001) for pigs fed the diet containing 3,000 ppm of Zn from ZnO, and the mean of pigs fed diets containing $ZnSO_4$ was intermediate. On d 33, the plasma Zn concentration was lowest (P<.0001) for pigs fed the control diet compared to either the mean of pigs fed diets containing $ZnSO_4$ or pigs fed the diet containing 3,000 ppm of Zn from ZnO. Increasing the concentration of Zn from $ZnSO_4$ increased (linear, P<.05) the plasma Zn concentrations on d 9, 19, and 33. Plasma Zn concentrations increased on d 19 and 13 only for pigs fed diets containing greater than 1,500 ppm of Zn from $ZnSO_4$ (cubic, P<.10) but plateaued on d 33 for pigs fed at least 2,500 ppm of Zn (cubic, P<.05).

These results suggest that overall growth performance of pigs did not benefit from diets containing increasing concentrations of Zn from $ZnSO_4$ or 3,000 ppm of Zn from ZnO. Pigs fed the basal control diet containing 165 ppm of Zn from ZnO provided by the trace mineral premix exhibited excellent growth performance for the duration of the trial. The lack of an added growth response from pigs fed diets containing 3,000 ppm of Zn from ZnO was possibly a reflection of the high health status of the pigs used in this experiment because one possible mode of action of the growth promoting response of high levels of Zn from ZnO is to prevent the occurrence of *E. coli* scours. These results also do not support those previously reported because no distinct correlation occurred between plasma Zn concentration and growth performance. From d 9 to 19, ADG numerically increased as plasma Zn concentration increased; however, no significant improvement in growth performance occurred when plasma Zn was higher than 1.5 mg/L.

In this experiment, pigs fed diets containing any concentration of $ZnSO_4$ from d 0 to 9 had lower ADFI compared to pigs fed either the control diet or pigs fed the diet containing 3,000 ppm of Zn from ZnO. Similarly, previous research conducted at Kansas State University reported that pigs fed 100 to 400 ppm of Zn from $ZnSO_4$ or the combination of $ZnSO_4$ and ZnO had lower feed intakes compared to pigs fed diets containing either no added Zn or 3,000 ppm of Zn from ZnO. More research needs to be conducted to determine the reason for this poor response to $ZnSO_4$.

Table 1. Diet Compositions (As-Fed Basis)

Ingredient, %	Day 0 to 5	Day 5 to 9	Day 9 to 19	Day 19 to 33
Corn	38.34	45.31	51.60	58.37
Dried whey	25.00	20.00	10.00	-
Soybean meal (46.5% CP)	12.18	21.30	28.50	34.39
Spray-dried animal plasma	6.75	2.50	-	-
Select menhaden fish meal	6.00	2.50	-	-
Lactose	5.00	-	-	-
Soy oil	2.00	2.00	3.00	3.00
Spray-dried blood meal	1.75	2.50	2.50	-
Monocalcium phosphate	.70	1.27	1.60	1.48
Limestone	.51	.77	1.0	.97
Cornstarch[a]	.85	.85	.85	.85
Salt	.25	.30	.30	.35
Vitamin premix	.25	.25	.25	.25
Trace mineral premix[b]	.15	.15	.15	.15
L-Lysine HCL	.15	.15	.15	.15
DL-Methionine	.12	.15	.10	.04
Total	100.00	100.00	100.00	100.00
Calculated analysis, %				
Lysine	1.70	1.55	1.40	1.30
Methionine	.48	.44	.39	.36
Ca	.90	.90	.85	.75
P	.80	.80	.75	.70

[a]Zn sources replaced corn starch to provide 500, 1,000, 1,500, 2,000, 2,500, or 3,000 ppm of Zn from $ZnSO_4$, or 3,000 ppm of Zn from ZnO.
[b]Provided per ton of complete feed: 36 g Mn; 150 g Fe; 150 g Zn from ZnO; 15 g Cu; 70 mg I; and 270 mg Se.

Table 2. Effects of Zinc from Increasing Levels of Zinc Sulfate on Weanling Pig Growth Performance[a,b]

		Zn from $ZnSO_4$						Zn from ZnO		Contrasts, P <[c]		
Item	Control	500	1,000	1,500	2,000	2,500	3,000	3,000	SEM	1	2	3
Day 0 to 9												
ADG, lb	.38	.29	.33	.35	.31	.34	.30	.38	.032	.09	.97	.08
ADFI, lb	.46	.34	.37	.40	.36	.38	.33	.48	.031	.006	.72	.002
F/G	1.22	1.19	1.19	1.16	1.23	1.15	1.11	1.27	.055	.37	.53	.09
Day 9 to 19												
ADG, lb[d]	.72	.72	.71	.78	.81	.82	.82	.76	.036	.13	.40	.67
ADFI, lb[e]	.94	.91	.87	1.00	.94	.98	.99	1.02	.039	.85	.14	.09
F/G[e]	1.32	1.30	1.24	1.29	1.17	1.21	1.19	1.35	.040	.06	.51	.008
Day 19 to 33												
ADG, lb	1.35	1.20	1.32	1.23	1.20	1.26	1.23	1.26	.036	.01	.08	.72
ADFI, lb	1.97	1.90	1.91	1.82	1.87	1.92	1.81	1.92	.054	.10	.49	.45
F/G[g]	1.46	1.59	1.45	1.49	1.55	1.52	1.47	1.53	.046	.34	.29	.67
Day 0 to 33												
ADG, lb	.89	.81	.86	.85	.84	.88	.85	.87	.024	.11	.47	.49
ADFI, lb	1.22	1.15	1.12	1.15	1.13	1.20	1.11	1.21	.040	.08	.92	.11
F/G[g]	1.37	1.42	1.30	1.35	1.34	1.37	1.29	1.40	.036	.56	.52	.16
Plasma, mg/L												
Day 9[d]	.71	.74	.76	1.05	1.13	1.45	1.59	1.77	.092	.0001	.0001	.0001
Day 19[df]	.92	.88	.81	1.22	1.49	1.96	2.19	1.82	.103	.0001	.0001	.0009
Day 33[dg]	1.12	1.21	1.16	1.23	1.86	2.29	2.22	1.91	.116	.0001	.0001	.06

[a]A total of 288 pigs (initially 13.4 lb and 18 d of age) with 4 or 5 pigs per pen and 8 pens per treatment.
[b]All diets contained 165 ppm of Zn from ZnO provided by the trace mineral premix.
[c]Contrasts were: 1) Control vs $ZnSO_4$, 2) Control vs 3,000 ppm of Zn from ZnO, and 3) $ZnSO_4$ vs 3,000 ppm of Zn from ZnO.
[d]Linear $ZnSO_4$, P<.05.
[e]Linear $ZnSO_4$, P<.10.
[f]Quadratic and Cubic $ZnSO_4$, P < .10.
[g]Cubic $ZnSO_4$, P<.05.

THE INTERACTIVE EFFECTS OF ZINC SOURCE AND FEED GRADE MEDICATION ON WEANLING PIG GROWTH PERFORMANCE[1]

J. C. Woodworth, M. D. Tokach[2], J. L. Nelssen, R. D. Goodband, J. T. Sawyer, K. A. Maxwell and T. M. Fakler[3]

Summary

Two hundred eight-eight weanling pigs (initially 12.3 lbs and 18 d of age) were used in a 27-d growth assay to determine the interactive effects of Zn source and feed grade medication on growth performance. Experimental treatments were arranged in a 2 × 3 factorial with main effects of medication (none or 50 g/ton of carbadox) and Zn source (none, 250 ppm of Zn from a Zn amino acid complex, or 3,000 ppm of Zn from ZnO). The results suggest that dietary Zn improved growth performance primarily from d 0 to 14 and feed grade medication improved growth performance from d 14 to 27. Pigs fed diets containing ZnO had better growth performance than pigs fed diets containing no additional Zn, and pigs fed diets containing ZnAA had intermediate responses.

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

Introduction

The benefits to growth performance of newly weaned pigs from feeding high levels of Zn from ZnO are well known. The use of feed-grade medications for improving growth and feed efficiency of swine is also a common practice. A past trial conducted at Kansas State University evaluated the interactive effects of diet complexity, ZnO, and feed-grade medication on growth performance of segregated early-weaned pigs. Added ZnO improved growth performance for the first 10 days, whereas medications improved growth performance primarily from d 10 to 27. However, no medication × ZnO interactions occurred. Recent research also has shown that lower levels of organic Zn sources may improve growth performance similar to high levels of ZnO when added to diets containing feed-grade medication. However, a series of experiments conducted at Kansas State University did not report similar growth responses between diets containing high levels of ZnO and diets containing lower levels of an organic Zn source. Diets used in these trials did not contain feed-grade medications; consequently, we did not know if the beneficial response to lower levels of organic Zn sources was dependent on the presence of such medications. Therefore, the objective of this trial was to further test the effects of an organic Zn amino acid complex (ZnAA) versus an inorganic Zn source (ZnO) in the presence and absence of feed-grade medication (carbadox) on weanling pig growth performance.

Procedures

A total of 288 weanling pigs (initially 12.3 lb and 18 d of age; PIC) was blocked by initial weight and allotted randomly to each of six dietary treatments in a 27 d growth

[1]Appreciation is expressed to Zinpro Corporation, Eden Prairie, MN, for partial financial support for this experiment. The authors also thank Eichman Brothers, St. George, KS, for the use of facilities and pigs for this experiment.

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

[3]Zinpro Corp., Eden Prairie, MN.

assay. Each treatment had six replications (pens) and eight pigs per pen.

The six experimental diets were arranged in a 2 × 3 factorial with main effects of feed-grade medication (none or 50 g/ton of carbadox) and Zn source (none, 250 ppm of Zn from a ZnAA, or 3,000 ppm of Zn from ZnO). The ZnAA used in this trial was AvailaZn, which is produced by the ZinPro Corporation, Eden Prairie MN, and contained 10% Zn.

All experimental diets were fed in meal form. Pigs were fed diets in three phases, with the first phase fed from d 0 to 7, the next from d 7 to 14, and the last fed from d 14 to 27. Diets were formulated to be similar to those fed in a commercial phase-feeding program. Zinc source and/or medication replaced cornstarch in the basal diets to form the experimental treatments, which were fed for the entire 27 d. All diets also contained 165 ppm of Zn from ZnO provided by the trace mineral premix.

Pigs were housed in an environmentally controlled nursery in 5 × 5 ft pens on a commercial farm in northeast Kansas. Pens contained one self-feeder and two nipple waters to provide ad libitum access to feed and water. Pigs were weighed and feed disappearance was measured on d 0, 7, 14, 21 and 27 to determine ADG, ADFI, and F/G.

Data were analyzed as a 2 × 3 factorial in a randomized complete block design using the general linear model (GLM) procedure of SAS. Data were analyzed for main effects (feed-grade medication and Zn source) and two-way interactions using pen as the experimental unit. Orthogonal contrasts were used to compare the Zn treatments.

Results and Discussion

From d 0 to 7, different Zn sources and/or medication had no effect (P>.10; Table 2) on ADG, ADFI, or F/G. From d 7 to 14, pigs fed diets containing ZnO had greater (P<.03) ADG and ADFI compared to pigs fed diets containing no additional Zn or ZnAA. Feed to gain ratio of pigs fed diets containing ZnO was better (P<.004) than that of pigs fed diets containing no additional Zn and tended to be better (P<.08) than that of pigs fed diets containing ZnAA. Pigs fed diets containing ZnAA had similar (P>.10) ADG, ADFI, and F/G compared to pigs fed diets containing no additional Zn. Feed medication had no effect (P>.10) on ADG, ADFI, or F/G.

From d 0 to 14, ADG of pigs fed diets containing ZnO was greater (P<.05) than that of pigs fed diets containing ZnAA or no additional Zn, and the ADG of pigs fed diets containing ZnAA tended to be greater (P<.07) than that of pigs fed diets containing no additional Zn. Average daily feed intake of pigs fed diets containing ZnO was greater (P<.007) than that of pigs fed diets containing no additional Zn and tended to be greater (P<.08) than that of pigs fed diets containing ZnAA. Feed to gain ratio was not different (P>.10) between pigs fed diets containing ZnO or ZnAA; however, both had better (P<.04) F/G than pigs fed diets containing no additional Zn. Feed medication did not influence (P>.10) growth performance.

From d 14 to 27, the different Zn sources did not affect (P>.10) ADG. Average daily feed intake of pigs fed diets containing ZnO was greater (P<.05) than that of pigs fed diets containing either ZnAA or no additional Zn; however, no difference (P>.10) occurred between these two sources. Feed to gain ratio of pigs fed diets containing ZnO was poorer (P<.04) than that of pigs fed diets containing no additional Zn, and tended to be poorer (P<.08) than that of pigs fed diets containing ZnAA. No difference (P>.10) in F/G occurred between pigs fed diets containing ZnAA and pigs fed diets containing no additional Zn. Pigs fed diets containing medication tended to have greater (P<.08) ADG and ADFI compared to pigs fed diets containing no medication; however, F/G was not affected (P>.10).

From d 0 to 27, pigs fed diets containing ZnO had greater (P<.04) ADG than pigs fed diets containing no additional Zn. Average daily gain of pigs fed diets containing ZnAA

was similar (*P*>.10) to that of pigs fed diets containing no additional Zn or ZnO. Average daily feed intake was greater (*P*<.03) for pigs fed diets containing ZnO compared to pigs fed diets containing either ZnAA or no additional Zn, and no difference (*P*>.10) occurred between these two sources. Feed to gain ratio was not affected (*P*>.10) by the different Zn sources. Pigs fed diets containing medication had similar (*P*>.10) ADG, ADFI, and F/G compared to pigs fed diets containing no medication.

The results of this trial resembled those of the previous Kansas State University experiment showing a beneficial response to ZnO for the first 14 days followed by an increased response to dietary medication after d 14. The loss of an ADG response from feeding high levels of ZnO after approximately d 14 is similar to past research showing that growth performance can be depressed if high levels of ZnO are fed for extended periods of time. In this trial, pigs fed diets containing Zn from ZnO had improved growth performance compared to pigs fed diets containing no additional Zn. Pigs fed diets containing ZnAA had intermediate growth responses. Previous research at Kansas State University also has shown that pigs fed diets containing lower levels of Zn from ZnAA exhibited intermediate growth performance compared to pigs fed diets containing high concentrations of Zn from ZnO and pigs fed diets containing no added ZnO.

In conclusion, our data suggest that both added Zn and feed-grade medication are effective at improving growth performance of weanling pigs. The Zn responses were observed primarily for the first portion of the trial, whereas the medication response was observed at the end of the experiment. Our data also suggest that high levels of Zn from ZnO improved growth performance more than lower levels of Zn from a Zn amino acid complex.

Table 1. Diet Compositions (As-Fed Basis)

Ingredient, %	Day 0 to 7	Day 7 to 14	Day 14 to 27
Corn	37.81	44.78	51.07
Dried whey	25.00	20.00	10.00
Soybean meal (46.5% CP)	12.18	21.30	28.50
Spray-dried animal plasma	6.75	2.50	-
Select menhaden fish meal	6.00	2.50	-
Lactose	5.00	-	-
Soy oil	2.00	2.00	3.00
Spray-dried blood meal	1.75	2.50	2.50
Monocalcium phosphate	.69	1.26	1.59
Limestone	.50	.76	.99
Cornstarch[a]	1.40	1.40	1.40
Salt	.25	.30	.30
Vitamin premix	.25	.25	.25
L-Lysine HCL	.15	.15	.15
Trace mineral premix[b]	.15	.15	.15
DL-Methionine	.12	.15	.10
Total	100.00	100.00	100.00
Calculated analysis, %			
Lysine	1.70	1.55	1.40
Methionine	.48	.44	.39
Ca	.90	.90	.85
P	.80	.80	.75

[a]Medication, ZNAA, and ZnO replaced cornstarch to provide the experimental treatments.
[b]Provided per ton of complete feed: 36 g Mn; 150 g Fe; 150 g Zn from ZnO; 15 g Cu; 270 mg I; and 270 mg Se.

Table 2. Interactive Effects of Zinc Source and Feed Grade Medication on Growth Performance of Weanling Pigs[a]

		No Medication			Medication[c]				Main Effects, *P* <		Interaction, *P* <	Contrasts, *P* <		
Item	Zn Source[b]	Control	ZnAA	ZnO	Control	ZnAA	ZnO	SEM	Zn Source	Medication	Zn Source × Medication	1	2	3
Day 0 to 7														
ADG, lb		.25	.28	.27	.24	.31	.28	.029	.51	.87	.91	.24	.62	.48
ADFI, lb		.37	.39	.37	.33	.35	.39	.028	.66	.63	.74	.56	.73	.36
F/G		1.57	1.58	1.41	1.42	1.18	1.47	.109	.70	.15	.22	.42	.67	.71
Day 7 to 14														
ADG, lb		.54	.59	.73	.49	.59	.75	.044	.0001	.76	.66	.10	.001	.0001
ADFI, lb		.78	.81	.97	.80	.88	.95	.048	.009	.58	.71	.32	.03	.002
F/G		1.44	1.40	1.34	1.69	1.52	1.28	.081	.009	.10	.15	.21	.08	.004
Day 0 to 14														
ADG, lb		.40	.43	.50	.36	.45	.51	.030	.003	.92	.72	.07	.05	.0004
ADFI, lb		.57	.60	.67	.57	.62	.67	.033	.04	.89	.94	.32	.08	.007
F/G		1.44	1.40	1.35	1.59	1.39	1.31	.057	.007	.42	.18	.04	.28	.002
Day 14 to 27														
ADG, lb		1.02	.99	1.09	1.13	1.12	1.12	.040	.71	.06	.68	.80	.44	.60
ADFI, lb		1.40	1.37	1.54	1.49	1.51	1.66	.042	.07	.08	.96	.91	.04	.05
F/G		1.39	1.40	1.42	1.32	1.34	1.48	.047	.09	.62	.31	.77	.08	.04
Day 0 to 27														
ADG, lb		.70	.70	.78	.73	.77	.81	.026	.11	.17	.82	.54	.14	.04
ADFI, lb		.97	.97	1.09	1.01	1.04	1.15	.032	.03	.17	.95	.77	.03	.02
F/G		1.40	1.39	1.40	1.38	1.36	1.42	.037	.62	.70	.67	.58	.32	.65

[a]Values represent the means of 288 pigs (initially 12.3 lb and 18 d of age) with eight pigs per pen, and six pens per treatment.
[b]Zinc Source: Control = no additional Zn; ZNAA = 250 ppm of Zn from ZnAA; and ZnO = 3,000 ppm of Zn from ZnO.
[c]Medication represents 50 g/ton of carbadox.
[d]Contrasts were: 1) Control vs. ZnAA, 2) ZnAA vs. ZnO, and 3) Control vs. ZnO.

EFFECTS OF PELLETING AND PELLET CONDITIONING TEMPERATURES ON WEANLING PIG PERFORMANCE[1]

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Summary

Two studies were conducted to evaluate the effects of pelleting and pellet conditioning temperature of diets containing 5% spray-dried animal plasma (SDAP) on weanling pig growth performance. In Exp. 1, conditioning temperatures evaluated were 140, 150, 160, and 170°F. In Exp. 2, pellet conditioning temperatures were 140, 155, 170, 185, and 200°F. The results suggest that pellet conditioning temperatures above 170°F decrease weanling pig performance from d 0 to 7 after weaning. Pellet conditioning temperature should not exceed 170°F (exit temperature of 180°F) for nursery diets containing 5% SDAP.

(Key Words: Weanling Pigs, Spray-Dried Animals Plasma, Pellet Conditioning Temperature.)

Introduction

Numerous trials have demonstrated improved ADG and F/G in pigs fed pelleted diets versus meal diets. Because starter diets typically contain specialty ingredients, such as dried whey and spray-dried animal plasma (SDAP), making a high quality pellet can be challenging. Some heat and steam are required in the pelleting process, but too much heat could potentially burn or scorch some of the specialty ingredients and reduce their nutritional value. Therefore, the objective of this experiment was to determine the effects of pellet conditioning temperature of a starter diet containing SDAP and spray-dried whey.

Procedures

General. Two 28 d growth assays were used to determine the effects of pelleting and pellet conditioning temperatures of starter diets fed to weanling pigs. Pigs (PIC L326 × C22) were housed in an environmentally regulated nursery at the Kansas State University Swine Teaching and Research Center in 5 ft × 5 ft pens and were provided ad libitum access to feed and water. Both experiments used seven pens (replications) per treatment, and each pen contained six pigs. The trials were divided into two phases, with the experimental diets fed from d 0 to 14 after weaning (Table 1). From d 14 to 28, a common corn-soybean meal-based diet containing 10 % dried whey and 2.5 % dried blood cells was fed in a meal form (Table 1).

The pelleted diets were conditioned with a 10-second retention time and then pelleted (5/32 in. diameter) using a Master Model HD 1000 series California Pellet Mill equipped with a die of 1.25 in. effective thickness. Samples of the pelleted diets were collected to determine pellet exit temperatures and pellet durability index (PDI).

Pigs were weighed and feed disappearance was determined on d 0, 7, 14, 21, and

[1]The authors thank American Protein Corp. for providing the spray-dried animal plasma and partial financial support.

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

[3]Food Animal Health and Management Center.

[4]American Protein Corp., Ames, IA.

28 after weaning to calculate ADG, ADFI, and F/G. Data were analyzed in a randomized complete block design with pen as the experimental unit.

Experiment 1. Two hundred fifty-two weanling pigs (13.2 lb and 21 d of age) were used. Experimental treatments consisted of a corn-soybean meal control diet (1.4% lysine and 15% dried whey) with no spray-dried animal plasma (SDAP) fed in a meal form or the control diet with 5% SDAP replacing soybean meal on a equal lysine basis also fed in a meal form. Additional treatments were the 5% SDAP diet pelleted at conditioning temperatures of 140, 150, 160, or 170°F. Corresponding exit temperatures were 155, 166, 171, and 176°F, and corresponding PDI's were 95.7, 92.7, 92.9, and 92.6, respectively.

Experiment 2. Two hundred fifty-two weanling pigs (13.8 lb and 22 d of age) were used in the 28 d growth assay. Experimental treatments were the control diet (containing no SDAP) from Exp. 1 pelleted at a conditioning temperature of 140°F or one of five diets containing 5 % SDAP pelleted at conditioning temperatures of 140, 155, 170, 185, or 200°F. Corresponding exit temperatures were 158, 158, 169, 180, 185, and 200°F with PDI's of 94.9, 96.7, 95.2, 93.7, 94.9, and 96.1.

Results and Discussion

Experiment 1. From d 0 to 7 and d 0 to 14, pigs fed the control diet had decreased (P<.08) ADG, ADFI, and F/G compared to the mean of pigs fed diets containing 5% SDAP. Although not significant, among pigs fed diets containing SDAP from d 0 to 7, those fed the pelleted diets had an 8% increase in ADG and 12% better feed efficiency than pigs fed the diet in meal form. From day 0 to 14, pellet conditioning temperature had no effect on pig performance.

From d 14 to 28, pigs previously fed the control diet had increased (P<.02) ADG and better F/G than animals previously fed diets containing 5% SDAP. From d 14 to 28, feed efficiency improved as pellet conditioning temperature was increased in the diet previously fed from d 0 to 14 (linear, P<.08). Overall (d 0 to 28), no effects of feeding SDAP or pellet conditioning temperature used from d 0 to 14 were observed (Table 2).

Experiment 2. From d 0 to 7, pigs fed the 5% SDAP diet conditioned at 140°F tended (P<.12) to have greater ADG and greater (P<.05) ADFI compared to pigs fed the control diet without SDAP. From d 0 to 7, ADG was similar as pellet conditioning temperature increased to 170°F, but then decreased with conditioning temperatures above 170°F (quadratic, P<.03). From d 0 to 7, increasing conditioning temperature also decreased feed intake (linear, P<.002), with the most pronounced decrease observed after 170°F. From d 0 to 14, increasing pellet conditioning temperature had no effect on ADG or ADFI, but F/G improved with increasing conditioning temperature (linear, P<.02), with pigs fed diets conditioned at 170°F having the best F/G.

From d 14 to 28, pigs previously fed the control diet had improved (P<.08) feed efficiency compared to pigs fed the diet containing 5% SDAP conditioned at 140°F. Pellet conditioning temperature of the diet fed from d 0 to 14 had no effect on performance from d 14 to 28 (Table 3).

In conclusion, the results of these experiments suggest that diet preparation and formulation are critical for optimal performance in early-weaned pigs. Results also suggest that adding SDAP to weanling pig starter diets, whether pelleted or prepared in meal form, improves growth performance from d 0 to 7. Although no statistical differences in growth performance occurred between pigs fed meal diets and those fed pelleted diets, pigs fed pelleted diets demonstrated a 12% improvement in feed efficiency from d 0 to 7. Results also indicated that conditioning diets containing SDAP at temperatures above 170°F decreases growth performance of weanling pigs.

Table 1. Compositions of Experimental Diets

	Day 0 to 14[a]		
Ingredient, %	Control	5% SDAP	d 14 to 28[b]
Corn	44.64	51.47	53.79
Soybean meal (46.5% C.P.)	34.04	22.18	25.86
Spray-dried animal plasma	--	5.00	--
Dried whey	15.00	15.00	10.00
Soy oil	3.00	3.00	3.0
Monocalcium P (21% P)	1.40	1.32	1.89
Limestone	.95	1.00	0.81
Salt	.30	.30	0.25
Vitamin premix	.25	.25	0.25
L-lysine HCl	.15	.15	0.15
Trace mineral	.15	.15	0.15
DL-methionine	.10	.13	0.10
Zinc oxide	--	--	0.25
Medication[c]	--	--	1.00
Spray-dried blood cells	--	--	2.50

[a]Formulated to contain 1.4% lysine, 0.9% Ca, and 0.8% P.

[b]Fed in meal form to all pigs and formulated to contain 1.35% lysine, .85% Ca, and .75% P.

[c]Provided 50 g/ton carbodox.

Table 2. Effects of Pelleting and Increasing Pelleting Temperature on Weanling Pig Performance (Exp. 1)[a]

	Meal Diets		Pellet Conditioning Temperature (°F)					Contrast (P<)[c]			
Item	Control	5% SDAP	140	150	160	170	SEM	1	2	3	4
Treatment[b]	1	2	3	4	5	6					
PDI[d]	-	-	95.7	92.7	92.9	92.6					
Day 0 to 7											
ADG, lb	.31	.43	.48	.47	.48	.45	.028	.001	.21	.53	.65
ADFI, lb	.52	.59	.59	.58	.55	.56	.023	.05	.37	.25	.56
F/G	1.86	1.42	1.28	1.24	1.17	1.27	.12	.001	.19	.87	.55
Day 0 to 14											
ADG, lb	.42	.56	.55	.60	.55	.53	.026	.001	.94	.39	.24
ADFI, lb	.73	.82	.78	.80	.76	.77	.027	.08	.15	.55	.80
F/G	1.75	1.49	1.44	1.34	1.39	1.45	.053	.001	.15	.67	.16
Day 14 to 28											
ADG, lb	1.42	1.36	1.36	1.32	1.33	1.37	.025	.02	.56	.62	.13
ADFI, lb	1.81	1.82	1.84	1.81	1.79	1.80	.041	.98	.82	.41	.69
F/G	1.28	1.34	1.36	1.38	1.35	1.31	.021	.01	.71	.08	.21
Day 0 to 28											
ADG, lb	.92	.96	.95	.96	.94	.95	.022	.42	.38	.31	.97
ADFI, lb	1.27	1.32	1.31	1.30	1.28	1.27	.029	.42	.38	.31	.96
F/G	1.39	1.38	1.38	1.36	1.36	1.35	.020	.34	.44	.30	.95

[a]Two hundred fifty-two weanling pigs were used (initially 13.2 lb) with six pigs per pen and seven pens per treatment.

[b]Treatment 1 contained no spray-dried animal plasma (SDAP). Treatments 2, 3, 4, 5, and 6 contained 5% SDAP.

[c]Contrasts: 1=Control (1) vs Plasma (Mean of 2, 3, 4, 5, and 6). 2=Meal (2) vs Pellet (Mean of 3, 4, 5, and 6).
3=Linear effect of conditioning temperature (3, 4, 5, and 6). 4=Quadratic effect of conditioning temperature (3, 4, 5, and 6).

[d]Pellet Durability Index (Standard: ASAE S269.3).

Table 3. Effects of Increasing Pellet Conditioning Temperature on Weanling Pig Performance (Exp. 2)[a]

		Pellet Conditioning Temperature (°F)						Contrast (P<)[c]		
Item	Control[b]	140	155	170	185	200	SEM	1	2	3
PDI[d]	94.9	96.7	95.2	93.7	94.9	96.1				
Day 0 to 7										
ADG, lb	.51	.57	.57	.60	.52	.47	.025	.12	.004	.03
ADFI, lb	.53	.59	.58	.59	.55	.49	.021	.05	.002	.12
F/G	1.05	1.05	1.01	.99	1.05	1.08	.040	.99	.41	.21
Day 0 to 14										
ADG, lb	.52	.52	.51	.57	.55	.54	.021	.88	.20	.29
ADFI, lb	.65	.69	.68	.69	.69	.67	.023	.23	.64	.60
F/G	1.25	1.35	1.35	1.22	1.24	1.24	.042	.23	.02	.36
Day 14 to 28										
ADG, lb	1.38	1.38	1.33	1.37	1.38	1.38	.038	.86	.58	.63
ADFI, lb	1.82	1.88	1.80	1.87	1.87	1.94	.058	.39	.34	.31
F/G	1.32	1.37	1.36	1.36	1.35	1.40	.026	.08	.44	.30
Day 0 to 28										
ADG, lb	.95	.95	.92	.97	.97	.96	.025	.88	.32	.92
ADFI, lb	1.23	1.28	1.24	1.28	1.28	1.30	.038	.28	.54	.53
F/G	1.30	1.36	1.35	1.32	1.32	1.36	.023	.10	.64	.19

[a]Two hundred fifty weanling pigs were used (initially 13.8 lb) with six pigs per pen and seven pens per treatment.

[b]Control contained no spray-dried animal plasma and was pelleted at 140°F. All other diets contained 5% SDAP and were pelleted at their respective temperatures.

[c]Contrasts: 1=Control vs 140°F. 2=Linear effect of conditioning temperature. 3=Quadratic effect of conditioning temperature.

[d]Pellet Durability Index (Standard:ASAE S269.3).

EFFECTS OF DIET PROCESSING METHOD ON GROWTH PERFORMANCE OF SEGREGATED EARLY-WEANED PIGS[1]

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Summary

A 28-d growth trial was conducted to evaluate the effects of different diet processing methods on growth performance of segregated early-weaned pigs. From d 0 to 14, pigs were fed diets processed by one of four different methods: meal, universal pellet cooker (UPC), expanded, or pelleted. Pigs fed pelleted or UPC diets had improved ADG and F/G, and pigs fed meal diets had the poorest ADG and F/G. From d 14 to 28, pigs were fed one of six diets consisting of complex meal and expanded diets and two (least cost and complex) UPC and pelleted diets. From d 14 to 28, pigs fed the complex pelleted diet had numerically the highest ADG and best F/G compared to pigs in the other treatments; however, ADG and F/G were not significantly different from those of pigs fed the meal diet. Complex pelleted or UPC diets improved growth performance compared to least cost diets. Thermal-processed, least-cost diets will not elicit similar or improved growth performance compared to complex diets. These data suggest that processing techniques influence growth performance more in the early nursery phases than in later phases, and that pigs fed UPC or pelleted diets have the best growth performance.

(Key Words: Weanling Pigs, Diet Processing, Growth.)

Introduction

Diet processing, such as pelleting, has been shown consistently to improve feed efficiency of pigs. Other thermal processing techniques, such as extruding or expanding, have been shown to improve growth performance in some trials; however, no benefits were observed in others. The Universal Pellet Cooker (UPC), a new diet processing technique developed by Wenger®, combines thermal processing technology with the benefits of pelleting. This technology should result in a diet form that could elicit growth performance responses similar to or exceeding those observed from pelleting.

Complex diets containing high levels of milk products or specialty protein sources have been shown to significantly improve growth performance compared to simple diets that contained no milk or specialty protein products; however, the complex diets are considerably more expensive. If further processing of simple diets could result in growth performance similar to that obtained from feeding complex diets to pigs, dietary cost could be reduced significantly. Thus, this trial was designed to compare the effects of different diet processing techniques (meal, UPC, pelleting, or expanding) on weanling pig growth performance. Secondly, we wanted to determine if simple diets processed by a standard pelleting technique or by UPC technology could elicit growth

[1]The authors thank Wenger®, Sabetha, KS, for partial funding and assistance and Eichmann Bros., St. George, KS, for the use of pigs and facilities for this experiment.

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

[3]Food Animal Health and Management Center.

performance similar to that of pigs fed complex diets in meal form.

Procedures

A total of 384 pigs (initially 12.0 lbs and 14 d of age) was used in a 28-d growth trial. Pigs were blocked on the basis of initial weight and randomly allotted to one of four dietary treatments with eight pigs per pen and eight (meal and expanded) or 16 (UPC and pelleted) replications (pens) per treatment. The diets were fed as meal, universal pellet cooker-conditioned pellets (UPC), standard-conditioned pellets, and expander-not pelleted forms. On d 14, pigs fed UPC or pelleted diets were used to further test the influence of diet complexity on processing technique. Pens of pigs fed these diets were allotted randomly to complex or least-cost formulations. Pigs previously fed meal or expanded diets were maintained on complex diets processed by the same method. Consequently, from d 14 to 28, there were eight replications of six treatments. Diet compositions are shown in Table 1.

Pigs were housed in an environmentally controlled nursery on a farm in northeast Kansas. Pens were 4 × 6 ft with tribar flooring, and pigs were allowed ad libitum access to feed through a five-hole self-feeder and water through a single water nipple. Weight gain and feed disappearance were determined on d 7, 14, 21, and 28 postweaning and were used to determine ADG, ADFI, and feed efficiency (F/G).

The standard-conditioned pelleted diet was steam preconditioned to 130°F with a cone pressure of 110 for the d 0 to 7 diet, 145°F and cone pressure of 110 for the d 7 to 14 diet, and 170°F for the diet fed from d 14 to 28. The standard-conditioned pellets were prepared with a 30 horsepower pellet mill (California Pellet Mill 1000 Series, Master H.D. Model). The expanded diet was steam conditioned to 140°F for the d 0 to 7 diet and 170°F thereafter. The expander cone pressure was computer monitored so that the expander energy input (net energy) was held constant at 12 kWh/t.

The data were analyzed as a randomized complete block design with pen as the experimental unit using the general linear model (GLM) procedures of SAS. An LSD test was used to test treatment means.

Results and Discussion

From d 0 to 7 (Table 2), pigs fed the meal diet had lower (P<.05) ADG compared to pigs fed UPC, pelleted, or expanded diets. Processing technique had no effect (P>.05) on ADFI. Feed to gain ratio was poorest (P<.05) for pigs fed the meal diet compared to all other diets.

From d 7 to 14, processing technique had no effect (P>.05) on ADG. Average daily feed intake was highest (P<.05) for pigs fed meal diets and lowest (P<.05) for pigs fed pelleted diets; pigs fed expanded and UPC-processed diets had similar but intermediate responses. Feed to gain ratio was best (P<.05) for pigs fed pelleted diets compared to all other diets. Pigs fed meal diets had poorer (P<.05) F/G than pigs fed UPC diets; however, F/G of pigs fed expanded diets was similar to that of pigs fed both meal and UPC diets.

From d 0 to 14, pigs fed meal diets had similar (P>.05) ADG compared to pigs fed expanded diets, but lower (P<.05) ADG than pigs fed UPC and pelleted diets. Pelleted diets elicited similar (P>.05) ADG compared to UPC diets, but higher (P<.05) ADG compared to expanded. No difference (P>.05) occurred in ADFI for different processing techniques. Feed to gain ratio was poorest (P<.05) for pigs fed meal diets compared to pigs in all other treatments. Pigs fed pelleted diets had better (P<.05) F/G compared to pigs fed expanded diets. Diets processed by UPC elicited similar (P>.05) F/G compared to pelleted and expanded diets.

From d 14 to 21 (Table 3), pigs fed meal, UPC complex, and pelleted complex diets had similar and higher (P<.05) ADG compared to pigs fed UPC least-cost diets, and pigs fed pelleted least-cost and expanded diets had intermediate responses. Average daily feed intake was highest (P<.05) for pigs

fed meal diets compared to pigs fed pelleted complex and expanded diets, and pigs fed UPC least-cost and complex and pelleted, least-cost diets had intermediate responses. Feed to gain ratio was poorest (P<.05) for pigs fed UPC least-cost diets compared to UPC complex, both pelleted diets, and expanded diets, but similar (P>.05) to F/G for pigs fed meal diets. Pigs fed pelleted complex diets had the lowest (P<.05) F/G compared to pigs fed meal or UPC least-cost diets, and all other diets resulted in intermediate responses.

From d 21 to 28, ADG was highest (P<.05) for pelleted complex diets compared to UPC least cost diets, and all other diets elicited similar and intermediate responses. Processing technique had no effect (P>.05) on ADFI and F/G.

From d 14 to 28, pigs fed pelleted complex diets had higher (P<.05) ADG compared to those fed both UPC diets, the pelleted least-cost diet, and the expanded diet. Average daily gain was lowest (P<.05) for pigs fed UPC least-cost diets compared to pigs fed meal and pelleted complex diets; those fed all other diets had intermediate responses. Average daily feed intake was highest (P<.05) for pigs fed meal diets compared to pig fed UPC and pelleted, least-cost diets and expanded diets. Feed to gain ratio was not different (P>.05) among diets.

In this trial, processing technique elicited the greatest response from d 0 to 14. Pigs fed UPC or pelleted diets had similar growth performance from d 0 to 14, but both processing techniques improved ADG and F/G compared to meal diets. From d 14 to 28, processing technique did not improve growth performance compared to pigs fed meal diets. Pigs fed complex UPC or pelleted diets had improved growth performance compared to those fed the UPC and pelleted, least-cost formulations. This suggests that increased diet processing can not replace diet complexity to support maximum growth performance of pigs.

Table 1. Diet Compositions (As-Fed Basis)

Ingredient, %	SEW Diet[a]	Transition Diet[b]	Complex II[c]	Least Cost Phase II[d]
Corn	34.59	41.59	51.49	53.89
Dried whey	25.00	20.00	10.00	-
SBM, 46.5%	12.39	21.39	28.00	37.79
Plasma protein	6.69	2.50	-	-
Fish meal	6.00	2.50	-	-
Lactose	5.00	-	-	-
Choice white grease	5.00	5.00	3.00	3.00
Blood meal	1.75	2.50	2.50	-
Monocalcium phosphate	.76	1.35	1.69	2.0
Limestone	.47	.75	1.10	1.10
Zinc oxide	.37	.37	.25	.25
Vitamin premix	.25	.25	.25	.25
Salt	.20	.20	.35	.35
L lysine-HCl	.15	.15	.15	.15
Trace mineral premix	.15	.15	.15	.15
DL-methionine	.15	.13	.10	.10
Sow pack	.05	.05	-	-
Antibiotic	1.00	1.00	1.00	1.00
Total	100	100	100	100

[a]Diets were formulated to contain 1.70% lysine, .48% methionine, .90% Ca, .80% P and were fed from d 0 to 7. [b]Diets were formulated to contain 1.55% lysine, .46% methionine, .90% Ca, .80% P and were fed from d 7 to 14. [c]Diets were formulated to contain 1.40% lysine, .43% methionine, .85% Ca, .75% P and were fed from d 14 to 21. [d]Diets were formulated to contain 1.40% lysine, .43% methionine, .85% Ca, .75% P and were fed from d 21 to 28.

Table 2. The Effects of Diet Processing on Growth Performance of Segregated-Early-Weaned Pigs[a]

	Processing Technique				
Item	Meal	UPC	Pellet	Expanded	SEM
Day 0 to 7					
ADG, lb	.29[b]	.39[c]	.40[c]	.34[c]	.027
ADFI, lb	.37	.39	.40	.3[6]	.020
F/G	1.29[b]	1.00[c]	1.03[c]	1.08[c]	.055
Day 7 to 14					
ADG, lb	.81	.83	.85	.80	.023
ADFI, lb	.91[b]	.85[bc]	.81[c]	.85[bc]	.031
F/G	1.11[b]	1.02[c]	.96[d]	1.06[bc]	.026
Day 0 to 14					
ADG, lb	.55[b]	.61[cd]	.62[c]	.57[bd]	.020
ADFI, lb	.64	.62	.61	.60	.021
F/G	1.16[b]	1.01[cd]	.97[d]	1.06[c]	.022

[a]A total of 384 pigs (initially 12.0 lbs and 14 d of age), eight pigs per pen and eight (meal and expanded) or sixteen (UPC and pellet) replications per treatment.
[b,c,d]Values with in the same row lacking a common superscript differ (P<.05).

Table 3. The Effects of Diet Processing Method on Growth Performance of Segregated-Early-Weaned Pigs[a]

	Processing Technique						
	Meal	UPC		Pellet		Expanded	
Item	CX[b]	LC	CX	LC	CX	CX	SEM
Day 14 to 21							
ADG, lb	.90[c]	.73[d]	.89[c]	.84[cd]	.96[c]	.83[cd]	.047
ADFI, lb	1.68[c]	1.55[cd]	1.58[cd]	1.52[cd]	1.47[d]	1.42[d]	.060
F/G	1.95[cd]	2.30[d]	1.85[ce]	1.88[ce]	1.57[ef]	1.73[cf]	.127
Day 21 to 28							
ADG, lb	1.33[cd]	1.24[d]	1.27[cd]	1.29[cd]	1.44[c]	1.26[cd]	.065
ADFI, lb	1.83	1.59	1.64	1.61	1.70	1.63	.090
F/G	1.38	1.30	1.29	1.26	1.19	1.30	.068
Day 14 to 28							
ADG, lb	1.11[ce]	.96[d]	1.07[cd]	1.06[cd]	1.20[e]	1.04[cd]	.039
ADFI, lb	1.76[eh]	1.57[cd]	1.61[defi]	1.57[dfgi]	1.59[dghi]	1.52[ci]	.062

[a]A total of 384 pigs (initially 12.0 lb and 14 d of age), eight pigs per pen and eight pens per treatment.
[b]Diet: CX = complex and LC = least cost.
[c,d,e,f,g,h,i]Values within the same row lacking a common superscript differ (P<.05).

EFFECTS OF SOURCE AND LEVEL OF DIETARY LYSINE ON GROWTH PERFORMANCE OF PIGS FROM 24 TO 48 LB[1]

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Summary

Three hundred twenty, 24 lb nursery pigs were fed for 19 days to compare the effects of increasing dietary lysine from L-lysine HCl (L-Lys) or Peptide Plus™ (PP) on growth performance. Three dietary treatments (1.025, 1.15, and 1.275% lysine) were each formulated with L-Lys and PP. Negative and positive control corn-soybean meal-based diets were formulated to .90 and 1.275% lysine, respectively. Increasing dietary lysine to 1.275% from L-Lys or PP resulted in increased performance; however, pigs fed the positive control diet had the best overall performance.

(Key Words: Lysine, L-Lysine HCl, Peptide Plus, Pigs.)

Introduction

Numerous research trials have indicated that replacing intact protein sources with high levels of crystalline amino acids results in poorer feed efficiency and protein accretion. Recent research has shown that peptides may account for a large portion of dietary protein absorbed from the small intestine. Therefore, feeding a diet containing partially digested protein and peptides, compared with diets with intact proteins and/or free amino acids, may result in improved protein utilization and growth performance.

Peptide Plus™ (PP) is a chemically/enzymatically hydrolyzed bovine muscle protein source manufactured by Darling International Inc. Research by Darling indicated that performance of weanling pigs was enhanced when diets were supplemented with PP. Therefore, the objective of this study was to determine the effects of source and level of dietary lysine on growth performance of 24 to 48 lb pigs.

Procedures

Three hundred-twenty PIC (C22 × 355) barrows and gilt nursery pigs (24 lb.) were blocked by weight and randomly allotted to one of eight dietary treatments with five pigs per pen and eight pens per treatment. Pigs were housed with ad-libitum access to feed and water in the two environmentally controlled nursery barns at Kansas State University. There were four replication of each treatment in each barn. All pigs were fed the standard KSU SEW, Transition, and Phase II diets for 1 week each prior to initiation of the trial. Pigs were weighed individually and pen feed disappearance was calculated on day 7, 14 and 19.

Eight dietary treatments were used in the experiment (Table 1). The positive (1.275% lysine) and negative (.90% lysine) control diets were corn and soybean meal-based and formulated with no synthetic amino acids with the exception of DL-methionine in the positive control diet to maintain an ideal

[1]The authors thank Ross Hamilton of Darling International, Irving, TX, for technical assistance and providing the Peptide Plus™ used in this study.

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

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minimum ratio to lysine. Three dietary treatments (1.025, 1.15, and 1.275% lysine) were each formulated with L-Lys and PP. Minimum ideal ratios of isoleucine, methionine, methionine plus cystiene, threonine, tryptophan, and valine relative to lysine were maintained at 55, 28, 57, 65, 22, and 69% in all diets with synthetic amino acid additions. All diets were formulated to contain minimums of .80% Ca, .42% available P, .32% Na, .49% Cl, .73% K, and 1,571 kcal ME/lb.

Data were analyzed as a randomized complete block design with seven single degree of freedom contrast comparisons: 1) positive vs negative control; 2) positive control vs other 1.275% lysine diets; 3) linear effect of L-Lys; 4) quadratic effect of L-Lys; 5) linear effect of PP; 6) quadratic effect of PP; and 7) L-Lys vs PP.

Results and Discussion

Least square means for the entire 19-day study are presented in Table 2. For all criteria evaluated, pigs fed the positive control diet had improved performance compared to pigs fed the negative control diet (P<.01). Regardless of lysine source, ADG increased with increasing dietary lysine (P<.01); however, those pigs fed diets containing L-Lys had higher ADG than those fed diets containing PP (P<.05). Average daily feed intake tended to decrease linearly (P=.12), although F/G improved linearly with increasing levels of PP (P<.001). Pigs fed the positive control diet had decreased ADFI (P<.05) and improved F/G (P<.001) compared to pigs fed 1.275% lysine diets containing L-Lys or PP. Feed efficiency improved linearly (P<.001) and quadratically (P<.05) for those pigs fed diets with increasing lysine from L-Lys and linearly (P<.001) for those pigs fed increasing lysine from PP. Similar to ADG, pigs fed diets containing L-Lys had improved F/G (P<.001) compared to those fed diets containing PP. Final weight increased linearly (P<.01) with increasing dietary lysine from either L-Lys or PP, although those pigs fed PP were lighter (P<.05) than those fed diets containing L-Lys.

These data indicate that PP is a less bioavailable form of amino acids than synthetic amino acids. Also, pigs will consume more feed but convert it less efficiently when fed diets formulated with high levels of synthetic amino acids or PP compared to pigs fed diets based on corn and soybean meal. Further research opportunities include verifying the amino acid digestibility of PP; establishing the metabolizable and net energy content of PP; and determining why pigs as light as 24 lb will overconsume a low-protein, amino acid-fortified diet. These data also indicate that pigs from 24 to 48 lb require a diet with at least 1.275% lysine (3.68 grams of lysine per Mcal of ME) formulated to ideal amino acid ratios with corn, soybean, fat, and synthetic amino acids on a least-cost basis.

Table 1. Percentage Compositions of Experimental Diets

	Negative Control	L-Lysine HCl			Peptide Plus™			Positive Control
Ingredient	.90%[a]	1.025%	1.15%	1.275%	1.025%	1.15%	1.275%	1.275%
Corn	59.200	59.200	59.200	59.200	59.200	59.200	59.200	52.750
Soybean meal, 46.5%	24.700	24.700	24.700	24.700	24.700	24.700	24.700	37.675
Choice white grease	3.950	4.050	4.100	4.300	3.500	3.150	2.750	4.850
Corn starch	7.275	6.887	6.454	5.755	5.788	4.193	2.03	
Monocalcium phosphate, 21%	1.725	1.725	1.725	1.725	1.300	.900	.500	1.625
Limestone	1.000	.950	.900	.8500	.925	.850	.800	.925
Salt	.750	.6925	.635	.5775	.500	.255	.010	.750
Vitamin premix	.250	.250	.250	.250	.250	.250	.250	.250
Trace mineral premix	.150	.150	.150	.150	.150	.150	.150	.150
Calcium chloride		.0675	.125	.195	.2875	.5625	.8375	
Sodium bicarbonate		.084	.168	.2525				
Mecadox 2.5g/ton	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
L-Lysine HCl		.1595	.3185	.475				
Peptide Plus™					2.390	4.775	7.160	
L-Isoleucine				.035				.01
DL-Methionine		.025	.100	.165				
L-Threonine		.035	.120	.200			.015	
L-Tryptophan		.025	.055	.080	.010	.015	.025	
L-Valine				.090				
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis, %								
Crude protein	16.5	16.8	17.2	17.7	18.2	19.9	21.6	22.0
Lysine	.90	1.025	1.15	1.275	1.025	1.15	1.275	1.275

[a]Calculated lysine level in the diet.

Table 2. Effects of Source and Level of Dietary Lysine on Growth Performance (d 0 to 19) from 24 to 48 lb

	Negative Control	L-Lysine HCl			Peptide Plus™			Positive Control	
Item	.90[a]	1.025	1.15	1.275	1.025	1.15	1.275	1.275	SEM
ADG, lb/d [bcde]	1.18	1.24	1.31	1.35	1.25	1.23	1.30	1.35	.022
ADFI, lb/d [bfgh]	2.13	2.11	2.02	2.10	2.12	2.06	2.07	1.97	.035
F/G [bcdefi]	1.80	1.70	1.54	1.55	1.70	1.68	1.58	1.46	.020
Final weight, lb [bcde]	46.51	47.55	48.95	49.70	47.71	47.36	48.78	49.62	.425

[a]Calculated lysine level in the diet.
[b]Positive vs negative control (P<.01).
[c]Linear effect of L-lysine HCl (P<.01).
[dh]Linear effect of Peptide Plus™ (P<.01 and .12, respectively).
[e]L-Lysine HCl vs Peptide Plus ™ (P<.05).
[f]Positive control vs other 1.275% lysine diets (P<.01).
[gi]Quadratic effect of L-lysine HCl (P<.15 and .02, respectively).

INFLUENCE OF LYSINE LEVEL FED FROM 40 TO 80 LB ON GROWTH PERFORMANCE AND CARCASS COMPOSITION OF BARROWS AND GILTS[1]

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

Summary

A total of 1,200 pigs was used to determine the influence of lysine level fed from 40 to 80 lb on growth performance and carcass composition. Barrows and gilts were fed corn-soybean meal-based diets with 6% added fat formulated to .80, .95, 1.10, 1.25, or 1.40% total lysine. Increasing dietary lysine improved ADG and F/G in a linear and quadratic manner with optimal ADG at 1.10% lysine and optimal F/G at 1.40% lysine. Economic returns over feed costs were similar at 1.10, 1.25, and 1.40% lysine.

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

Introduction

Numerous trials have examined the lysine requirements of PIC barrows and gilts. The lysine requirement estimates for the growing phase range from .95% to 1.4% in various research trials. Lysine predictions from ultrasound scans consistently estimate requirements of 1.3% at 50 lb and 1.1% or above at 100 lb. Another concern is whether any benefit from reducing backfat or increasing protein deposition from 40 to 80 lb will be maintained at market weight. Thus, the objective of this trial was to determine the most cost-effective lysine level to feed from 40 to 80 lb for PIC barrows and gilts.

Procedures

A total of 600 barrows and 600 gilts (PIC C-22 × 337) was used in this experiment. Pigs were penned by gender and housed in a 1,200-head finishing barn equipped with 48 pens (25 pigs per pen). Pigs were sorted by sex as they were moved into the nursery. When moved from the nursery into the finishing barn, pigs were allotted randomly to pens within their gender group. Average initial weight was 41.7 lb.

The finishing barn was a double curtain-sided, deep pit barn. It operates on manual ventilation during warm weather and is equipped with automatic ventilation for cold weather. Floor was totally slatted concrete. Pens were equipped with one four-hole self-feeder and one cup waterer. Pen dimensions were 10 ft × 18 ft providing 7.2 sq ft per pig.

Group weights of all the pigs in each pen were obtained every 2 weeks. Diet phase changes occurred at 4-week intervals. Feeders were vacuumed on the day that diet phases were changed, and the remaining amounts of feed recorded. All pigs in a pen were weighed at market before shipping to the processing plant. The pigs in each pen were marked with a different tattoo prior to marketing to allow carcass data to be collected and attributed back to each pen. Standard carcass criteria were measured, including carcass weight, fat depth, loin depth, lean percentage, and fat-free lean index.

[1]Appreciation is expressed to Global Ventures for the use of pigs and facilities; Pipestone Research Partners for partial financial support; and Steve Rops, Marty Heintz, and Robert Powell for technical assistance.

[2]Food Animal Health and Management Center.

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

The trial was arranged with a split plot design. Gender served as the whole plot, and dietary treatments were assigned within the subplot for the first 28 days of the experiment (approximately 40 to 80 lb). Diets were corn-soybean meal-based and were formulated to contain 6% added choice white grease (Table 1). Total lysine levels tested in the experiment were .80, .95, 1.10, 1.25, and 1.40%. The corn and soybean meal levels in the diet were altered to achieve the dietary lysine levels. Diets contained no more than .05% crystalline lysine to ensure that lysine was first liminting in all diets. All pigs were fed the same nursery diet containing 1.40% lysine prior to the start of the experiment. All pigs were fed a common diet in a subsequent 28-d phase. This diet was formulated to 1.25% lysine for gilts and 1.10% lysine for barrows. The diets contained 6% added fat. All other nutrients met or exceeded the requirement estimates provided by NRC (1998). Vitamin and trace mineral concentrations were similar to KSU recommendations.

Results and Discussion

Increasing dietary lysine from .80 to 1.40% increased ADG and F/G in a linear and quadratic manner (P<.01; Table 2). The greatest response in ADG occurred when lysine was increased from .80 to 1.10%, and a small further numeric increase occurred for 1.40% lysine. The greatest response in F/G occurred when lysine was increased from .80 to .95%, and further steady reductions in F/G occurred with every incremental increase in lysine.

At the end of the 28-d study, all pigs were scanned ultrasonically for loin area and 10th rib fat depth. Loin area was unaffected by dietary treatment; however, 10th rib fat depth decreased in a linear (P<.01) and quadratic (P<.02) manner as dietary lysine increased. The largest reduction in fat depth was observed as dietary lysine increased from .80 to .95%.

Subsequent performance from d 28 to 58 was not influenced by dietary lysine level fed from d 0 to 28 of the experiment.

An analysis was conducted to determine the dietary lysine level that provided the greatest economic return (Table 3). When examining cost per lb of gain, diets formulated to .95, 1.10, 1.25, or 1.40% provided similar values ($.092 to $.093). A slightly different answer resulted when a value was placed on the extra weight gain. Diets formulated to 1.10, 1.25 or 1.40% lysine provided an extra $1 to $1.35 return over feed cost compared to the diet formulated to .95% lysine and an additional $2.11 to $2.44 return over feed cost compared to the diet formulated to .80% lysine. Note that in the return over feed cost analysis, the value of gain was fixed at $.40 per lb and did not take into account any potential changes in carcass characteristics as a result of dietary lysine level fed from 40 to 80 lb. Additional research needs to be conducted to determine if these differences in fat depth and loin area would be maintained at market. If these differences were maintained, the higher dietary lysine levels would be even more cost competitive.

In summary, the results of this experiment indicate that diets for pigs weighing 40 to 80 lb can be formulated with 1.10 to 1.40% lysine with similar economic benefits. The slight improvement in F/G at higher lysine levels offset the increase in diet cost to result in a similar return over feed cost. We should note that high-energy diets (6% choice white grease) were used in this experiment. The lysine:calorie ratios would be 3.07 to 3.90 g/Mcal ME for the 1.10 and 1.40% lysine levels, respectively.

Table 1. Compositions of Experimental Diets

	Total Dietary Lysine, %				
Ingredient, %	.80	.95	1.10	1.25	1.40
Corn	72.15	66.75	61.38	55.65	49.98
Soybean meal, 46.5%	18.98	24.40	29.85	35.64	41.40
Choice white grease	6.00	6.00	6.00	6.00	6.00
Monocalcium phos, 21% P	1.30	1.28	1.25	1.20	1.13
Limestone	0.95	0.95	0.95	0.95	0.95
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin premix[a]	0.08	0.08	0.08	0.08	0.08
Trace mineral premix	0.15	0.15	0.10	0.10	0.10
L-Lysine HCl	0.05	0.05	0.05	0.04	0.03
Total	100.00	100.00	100.00	100.00	100.00
Calculated analysis					
Lysine, %	.80	.95	1.10	1.25	1.40
Isoleucine:lysine ratio, %	72%	72%	71%	72%	72%
Leucine:lysine ratio, %	176%	164%	155%	148%	144%
Methionine:lysine ratio, %	31%	29%	28%	27%	26%
Met & Cys:lysine ratio, %	66%	62%	58%	56%	55%
Threonine:lysine ratio, %	70%	68%	66%	66%	65%
Tryptophan:lysine ratio, %	21%	21%	21%	21%	21%
Valine:lysine ratio, %	89%	86%	83%	82%	81%
ME, kcal/lb	1,627	1,626	1,626	1,626	1,626
Protein, %	15.0	17.0	19.1	21.3	23.5
Ca, %	0.69	0.70	0.71	0.72	0.72
Available P, %	0.33	0.33	0.33	0.33	0.32
Lysine:calorie ratio, g/mcal ME	2.23	2.65	3.07	3.49	3.90

[a]The vitamin premix inclusion at 1.5 lb/ton provides same vitamin concentrations as 3 lb/ton of KSU vitamin premix.

Table 2. Influence of Dietary Lysine Level Fed from 40 to 80 lb on Growth Performance and Ultrasound Measurements

	Total Dietary Lysine, %						P <	
Item	.80	.95	1.10	1.25	1.40	SE	Linear	Quad.
Day 0 to 28								
ADG	1.24	1.33	.146	1.45	1.49	.02	.01	.01
ADFI	2.25	2.16	2.29	2.23	2.19	.03	NS	NS
F/G	1.84	1.63	1.58	1.53	1.48	.02	.01	.01
Weight on d 28	76.4	78.9	82.5	82.2	83.7	.7	.01	.03
Ultrasound measurements[a]								
Loin area, sq. in.	2.63	2.66	2.72	2.79	2.75	.08	NS	NS
10^{th} rib fat depth, in.	.16	.13	.14	.13	.13	.01	.01	.02
Subsequent performance, d 28 to 58								
ADG	1.83	1.72	1.83	.173	1.80	.03	NS	NS
ADFI	4.10	3.95	4.05	4.13	4.28	.09	.06	.08
F/G	2.24	2.31	2.21	2.38	2.37	.07	NS	NS

[a]Final weight (d 28) was used as a covariate for ultrasound measurements.

Table 3. Economic Value of Increasing the Dietary Lysine Level for Pigs from 40 to 80 lb

	Total Dietary Lysine, %				
Economic Calculations	.80	.95	1.10	1.25	1.40
Diet cost, $/ton	$109	$113	$117	$121	$125
Feed cost, $/pig	$3.44	$3.42	$3.76	$3.77	$3.83
Wt gain in 28 d, lb	34.6	37.3	40.9	40.7	41.7
Feed cost, $/lb gain	$0.099	$0.092	$0.092	$0.093	$0.092
Value of gain at $.40/lb, $/pig	$13.83	$14.91	$16.35	$16.27	$16.67
Return over feed cost, $/pig	$10.40	$11.49	$12.60	$12.50	$12.84
Extra return over .8% lysine		$1.09	$2.20	$2.11	$2.44

LACK OF INTERACTION BETWEEN LYSINE LEVELS FED IN GROWING AND FINISHING DIETS[1]

S. S. Dritz[2], M. D. Tokach[3], R. D. Goodband, J. L. Nelssen, Steve Rops[4], and Marty Heintz

Summary

A total of 1,200 pigs were used to determine whether dietary lysine level fed in the growing phase influenced the response to lysine level fed in the finishing phase. Pigs were fed either an adequate or low lysine level during the growing (60 to 170 lb) and/or finishing phase (170 to 265 lb). Feeding a deficient lysine level decreased ADG and F/G during the phase when the deficient diet was fed; however, lysine level fed in the growing phase did not influence the response in the finishing phase. Carcass parameters were influenced more by the lysine level fed in the finishing diets.

(Key Words: Lysine, Growing-Finishing Pigs, Compensatory Gain, Growth.)

Introduction

Several experiments have been conducted to determine the optimal lysine level for each phase of the growing-finishing period. Three of those experiments are presented in other articles in this report. An important and unanswered question relates to whether the response to lysine level in one phase is influenced by the level fed in a previous phase of growth. For example: If we feed a deficient lysine level in the growing diet, will the pigs respond differently to graded lysine levels in the finishing diet? Thus, the objective of this experiment was to determine whether the growth response to various lysine levels fed in the growing period carries over to affect response to the lysine level fed in the finishing period.

Procedures

A total of 600 barrows and 600 gilts (PIC C-22 × 337) was used. Pigs were penned by gender and housed in a 1,200-head finishing barn equipped with 48 pens. Thus, there were 25 pigs per pen. Pigs were sorted by sex as they were moved into the nursery. When moved from the nursery into the finishing barn, pigs were allotted randomly to pens within their gender group. Average initial weight was 62.6 lb.

The finishing barn was a double curtain-sided, deep pit barn. It operates on manual ventilation during warm weather and is equipped with automatic ventilation for cold weather. The trial was conducted from January to June, 1999. The floor was totally slatted concrete. Pens were equipped with one four-hole self-feeder (Staco) and one cup waterer. Pen dimensions were 10 ft × 18 ft to provide 7.2 sq ft per pig.

Group weights of all the pigs in each pen were obtained every 2 weeks. Diet phase changes occurred at 4-week intervals. Feeders were vacuumed on the day that diet

[1]Appreciation is expressed to Global Ventures, Pipestone, MN for supplying the pigs, feed, and facilities for this experiment.

[2]Food Animal Health and Management Center.

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[4]Global Ventures, Pipestone, MN.

phases were changed, and the remaining amounts of feed recorded. Pigs in all pens were weighed at market before shipping to the processing plant. The pigs in each pen were marked with a different tattoo prior to marketing to allow carcass data to be collected and attributed back to each pen. Standard carcass criteria were measured including carcass weight, fat and loin depth, lean percentage, and fat-free lean index.

The trial was arranged with a split plot design. Gender served as the whole plot, and dietary treatments were the subplots. Dietary treatments were arranged as a 2 × 2 factorial to provide an adequate or low level of lysine (total protein) during the growing and finishing phases (Table 1). Diets were formulated in four phases (60 to 115 lb, 115 to 170 lb, 170 to 215 lb, and 215 lb to market). The actual lysine levels used for the adequate and low diets were slightly lower for the barrows compared to the gilts (Table 2). The adequate lysine levels were chosen based on the results of previous lysine titration studies conducted in the same facilities with pigs of the same genetics. The low levels were selected to be approximately 20% lower than the adequate levels.

All diets were corn-soybean meal based. Diets fed during phases 1 and 2 contained 6% added choice white grease. Diets fed during phases 3 and 4 did not contain any added fat. All other nutrients met or exceeded the requirement estimates provided by NRC (1998). Vitamin and trace mineral levels were similar to KSU recommendations.

Results and Discussion

No interactions occurred between dietary lysine levels fed in the growing and finishing phases. In other words, the lysine level fed in the growing phase had no influence on the response to the lysine level fed in the finishing phase. No carryover effects were found in this trial. Therefore, only main effect means are shown in Table 4.

The differences in performance and carcass composition between barrows and gilts were as expected. Barrows consumed more feed and grew faster than gilts during phases 1, 2, and 3 and for the overall trial. Gilts had better F/G during phases 2 and 3 and for the overall trial. Barrows had heavier carcass weights, more fat depth, and a lower percentage lean and fat free lean index. Although the expected differences between barrows and gilts were found, they responded similarly to dietary treatments.

Feeding a deficient lysine level in the growing phases (1 and 2) resulted in poorer ADG and F/G. Pigs fed the deficient lysine level during phases 1 and 2 weighed 3.3 lb less ($P<.10$) at the end of phase 2 than pigs fed the adequate lysine diet. This difference was maintained to the end of the trial (3.4 lb); however, the difference was not significant because of greater weight variation at the end of the trial. Lysine level fed in the growing diet did not influence carcass traits except for a small increase in fat-free lean percent for pigs fed the adequate lysine diets.

Feeding a deficient lysine level in the finishing phases (3 and 4) resulted in poorer ADG and F/G. The magnitude of the response was much greater than found with feeding deficient lysine levels in the growing phase. All carcass traits were improved by feeding the adequate lysine diets compared to the low lysine diets.

The results of this trial do not support the theory that lysine levels fed during one phase of production influence the response to lysine levels in another phase. Therefore, the lysine levels that are most economical during each individual phase of growth should be fed. Another view of these data is that pigs fed the low lysine diets during the growing phase did not demonstrate compensatory growth during the finishing phase. Further research is required to determine whether offering a lysine level above that fed in the adequate diet would have supported compensatory growth.

Table 1. Arrangement of Dietary Treatments[a]

	Adequate (G)[b]		Low (G)		
Phase	Adequate (F)	Low (F)	Adequate (F)	Low (F)	Wt. Range, lb
1	Adequate	Adequate	Low	Low	60 to 115
2	Adequate	Adequate	Low	Low	115 to 170
3	Adequate	Low	Adequate	Low	170 to 215
4	Adequate	Low	Adequate	Low	215 to 265

[a]Adequate and low refer to dietary lysine levels relative to the pigs estimated requirements.
[b]G = growing phase, F = finishing phase.

Table 2. Dietary Lysine Sequence, %

	Barrow		Gilt		
Phase	Adequate	Low	Adequate	Low	Wt. Range, lb
1	1.17	0.99	1.26	1.08	60 to 115
2	0.92	0.80	1.05	0.89	115 to 170
3	0.65	0.50	0.75	0.60	170 to 215
4	0.60	0.43	0.70	0.50	215 to 265

Table 3. Lysine:Calorie Ratio for Each Phase

	Barrow		Gilt		
Phase	Adequate	Low	Adequate	Low	Wt. Range, lb
1	3.24	2.76	3.50	3.01	60 to 115
2	2.56	2.23	2.92	2.48	115 to 170
3	1.95	1.50	2.25	1.80	170 to 215
4	1.80	1.27	2.10	1.50	215 to 265

Table 4. Main Effects of Gender and Adequate or Low Lysine Level during Each Phase

	Gender		Phases 1 and 2		Phases 3 and 4		
Item	Barrows	Gilts	Adequate	Low	Adequate	Low	SEM
Phase 1							
ADG, lb	1.87[a]	1.78[b]	1.84	1.81	1.81	1.85	0.02
ADFI, lb	3.26[a]	3.06[b]	3.13	3.19	3.13	3.19	0.03
FG	1.74	1.72	1.70[a]	1.76[b]	1.73	1.73	0.02
Phase 2							
ADG, lb	2.01[a]	1.94[b]	2.02[a]	1.94[b]	1.96	2.00	0.02
ADFI, lb	4.44[a]	4.07[b]	4.23	4.28	4.23	4.27	0.04
FG	2.21[a]	2.10[b]	2.10[a]	2.20[b]	2.16	2.14	0.03
Phase 3							
ADG, lb	1.45	1.48	1.47	1.46	1.58[a]	1.35[b]	0.03
ADFI, lb	4.84	4.56	4.77	4.64	4.68	4.72	0.06
FG	3.43[a]	3.13[b]	3.32	3.23	2.98[a]	3.58[b]	0.09
Phase 4							
ADG, lb	1.57	1.54	1.56	1.56	1.66[a]	1.45[b]	0.04
ADFI, lb	5.53	5.16	5.38	5.32	5.27	5.43	0.07
FG, lb	3.55	3.44	3.51	3.48	3.19[a]	3.81[b]	0.09
Phases 1 and 2							
ADG, lb	1.94[a]	1.86[b]	1.93[a]	1.88[b]	1.88	1.92	0.02
ADFI, lb	3.83[a]	3.55[b]	3.66	3.72	3.67	3.71	0.03
FG	1.98[a]	1.91[b]	1.90[a]	1.98[b]	1.95	1.94	0.02
Phases 3 and 4							
ADG, lb	1.51	1.51	1.52	1.51	1.62[a]	1.40[b]	0.03
ADFI, lb	5.19[a]	4.87[b]	5.08	4.98	4.98	5.08	0.05
FG	3.47[a]	3.26[b]	3.38	3.34	3.08[a]	3.65[b]	0.06
Overall							
ADG, lb	1.72[a]	1.68[b]	1.71	1.68	1.75[a]	1.65[b]	0.01
ADFI, lb	4.52[a]	4.21[b]	4.38	4.35	4.33	4.40	0.03
FG	2.63[a]	2.51[b]	2.56	2.59	2.48	2.67	0.02
Weight, lb							
Initial	62.6	62.6	62.7	62.5	62.8	62.4	1.1
End of phase 1	116.9	114.2	116.2	114.9	115.2	115.9	1.3
End of phase 2	173.3[a]	168.7[b]	172.6[c]	169.3[d]	170.2	171.8	1.3
End of phase 3	215.3[c]	211.5[d]	215.2	211.6	215.9[a]	210.9[b]	1.5
Final	262.6	258.4	262.2	258.8	266.6[a]	254.5[b]	2.3
Carcass data							
Live wt, lb	264.2[a]	257.6[b]	262.2	259.6	264.7[a]	257.1[b]	1.71
Carcass	199.4[a]	194.9[b]	198.3	196.1	201.4[a]	192.9[b]	1.16
Fat depth, in	0.78[a]	0.61[b]	0.69	0.70	0.67[a]	0.72[b]	0.01
Loin depth, in	2.27	2.30	2.29	2.28	2.35[a]	2.22[b]	0.01
Lean, %	53.8[a]	56.4[b]	55.2	55.0	55.6[a]	54.5[b]	0.12
Fat free lean, %	49.0[a]	50.9[b]	50.0[c]	49.8[d]	50.4[a]	49.5[b]	0.08
Optimal wt, %	88.4%	84.5%	87.3%	85.7%	88.8%[a]	84.1%[b]	1.7%

Different superscripts within the main effect signify differences [a,b](P<.05) and [c,d](P<.10).

EFFECTS OF INCREASING LYSINE:CALORIE RATIO AND DIETARY FAT ADDITION ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF GROWING-FINISHING GILTS[1]

M. De La Llata, S. S. Dritz[2], M. D. Tokach[3], R. D. Goodband, and J. L. Nelssen

Summary

An experiment using 1,200 gilts (60 to 260 lb) was conducted to determine the effects of increasing lysine:calorie ratio and dietary fat addition on growth performance and carcass characteristics. Dietary treatments were arranged in a 2 × 4 factorial with two levels of dietary fat (0 and 6%) and four lysine:calorie ratios in each of the four phases. The appropriate lysine:calorie ratios to maximize growth performance were: 3.56, 2.50 to 2.75, 2.04, and 1.72 from 60 to 100 lb, 100 to 165 lb, 165 to 220 lb, and 220 to 260 lb, respectively. These ratios equate to approximate total lysine levels of 1.15, .90, .75, and .58%, respectively, in corn-soybean meal-based diets with no added fat.

(Key Words: Lysine:Calorie Ratio, Fat, Lysine, Finishing Pigs.)

Introduction

A lysine:calorie ratio can be used to determine the lysine requirement based on the dietary energy concentration. Determining an accurate lysine:calorie ratio will ensure that the right amount of lysine is provided in diets varying in energy density. Several studies have been conducted to determine the appropriate lysine:calorie ratio and the influence of fat additions to growing-finishing pig diets on growth performance and carcass characteristics. However, most of these trials have been conducted in university research settings, where the responses to fat addition have been much smaller than those observed in pigs reared under field conditions. The difference in the magnitude of these responses might be due to the fact that feed intake is normally 25 to 40% higher in university research settings than under commercial conditions. Therefore, the objective of this experiment was to determine the effects of added fat and different lysine:calorie ratios on growth performance and carcass characteristics of growing-finishing gilts reared under commercial conditions.

Procedures

A total of 1,200 gilts (PIC C22 × 337) with an initial weight of 60 lb was used in this experiment. Pigs were allotted to one of eight dietary treatments in a completely randomized design with 25 pigs/pen and six pens/treatment. The finishing barn was equipped with 48 totally slatted concrete pens. Each pen was equipped with a four-hole dry self-feeder and one cup waterer. Pen dimensions were 10 ft × 18 ft, providing 7.2 sq ft/pig. The finishing facility is a double curtain-sided, deep pit barn and operates on manual ventilation during the summer and on automatic ventilation during the winter.

The corn soybean meal-based diets were arranged in a 2 × 4 factorial with two levels of fat (0 and 6% choice white grease) and

[1]Appreciation is expressed to Global Ventures for the use of pigs and facilities; to Pipestone Research Partners for partial financial support; and to Marty Heintz, Steve Rops, and Robert Powell for technical assistance.

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four lysine:calorie ratios in each phase. The four phases were 60 to 100, 100 to 165, 165 to 220, and 220 to 260 lb. Lysine:calorie ratios fed during each phase are shown in Table 1, and the corresponding lysine levels for each diet are shown in Table 2. Vitamin and trace mineral levels were similar to KSU recommendations, and all other nutrients met or exceeded the requirements estimates provided by NRC (1998).

Pigs weights by pen and feed disappearance were measured every 14 d to calculate ADG, ADFI, and F/G. Diet phase changes occurred every 28 d. At the termination of the study, pigs were sent to a USDA-inspected packing plant for collection of individual carcass data. The pigs in each pen were marked with a different tattoo prior to marketing to allow carcass data to be attributed back to each pen. The experiment was conducted from July to November, 1998.

Analysis of variance was used to analyze the data as a completely randomized design with a 2 × 4 factorial treatment arrangement using GLM procedures of SAS with linear and quadratic polynomial contrasts.

Results and Discussion

During phase 1 (60 to 100 lb), increasing the lysine:calorie ratio increased (linear, P<.01) ADG and decreased ADFI (quadratic P<.05), and F/G (linear P<.01; Table 3). The greatest response occurred when the lysine: calorie ratio was increased to the third level (3.56 g/Mcal). Adding 6% choice white grease to the diets increased (P<.01) ADG and decreased (P<.01) ADFI and F/G, similar to the response found in other trials.

During phase 2 (100 to 165 lb), increasing the lysine:calorie ratio increased ADG and decreased ADFI and F/G in a quadratic (P<.02) manner. The greatest response was obtained by increasing the lysine:calorie ratio to the second and third levels (2.50 to 2.75 g/Mcal). Increasing dietary fat form 0 to 6% increased (P<.03) ADG and decreased (P<.01) ADFI and F/G.

In phase 3 (165 to 220 lb), increasing the lysine:calorie ratio increased (linear P<.02) ADG and decreased (linear P<.01) F/G. The optimal response appeared to occur for the third and fourth lysine:calorie ratios (2.04 to 2.24). Adding fat to the diets did not affect (P>.48) ADG but decreased (P<.01) ADFI and F/G.

During phase 4 (220 to 260 lb), increasing the lysine:calorie ratio increased (linear P<.01) ADG and decreased (linear P<.01) F/G. The linear response indicates that the optimal lysine:calorie ratio was at or above the highest level fed in this phase (1.72 g/Mcal). Adding 6% fat to the diets did not affect ADG (P>.84) but decreased (P<.03) ADFI and F/G.

For the overall experiment, increasing the lysine:calorie ratio increased (quadratic P<.09) ADG and decreased (quadratic P<.05) F/G, with the optimal response at the third lysine:calorie ratio regimen. Increasing dietary fat from 0 to 6%, increased (P<.01) ADG and decreased (P<.01) ADFI and F/G.

Increasing the lysine:calorie ratio did not affect (P>.57) carcass yield. Backfat depth, loin eye depth, percent lean, and fat-free lean index were improved linearly (P<.01) by increasing the lysine:calorie ratio in the diet. Adding 6% dietary fat tended to increase backfat (P<.17) and decrease percent lean (P<.14) and fat-free lean index (P<.12).

The results from this experiment suggest that adding 6% fat to the diets decreases F/G by approximately 10%. Similar to other experiments, adding fat to the diet improved ADG during the growing phases (60 to 165 lb), but not in the finishing phases (165 to 260 lb). The greatest improvement in feed efficiency also was observed during earlier phases 1, 2, and 3 (12, 11, and 9%, respectively). Other research also demonstrates that adding fat only during phases 1, 2, and 3 would decrease the observed tendencies for reductions in percent lean and fat-free lean index.

These data also indicate that increasing the lysine:calorie ratio improves growth

performance. The quadratic response observed during phases 1 and 2 and for the overall data indicates that improvement in growth performance plateaus around the third lysine:calorie ratio. The strong linear response observed in carcass parameters indicates that the lysine requirement to maximize carcass traits is higher than that to maximize growth performance. It also suggests that carcass composition was heavily influenced by the linear response during the last phase of the experiment. More research is needed to verify the appropriate lysine: calorie ratio during this phase.

In summary, the appropriate lysine:calorie ratios to maximize growth performance of growing-finishing gilts were: 3.56, 2.50 to 2.75, 2.04, and 1.72 for phases 1, 2, 3, and 4, respectively. These ratios equate to approximate total lysine levels of 1.15, .90, .75, and .58%, respectively, in corn-soybean meal-based diets with no added fat.

Table 1. Lysine:Calorie Ratios

	Lys:Cal Ratio (g lysine/Mcal ME)			
Phase	1	2	3	4
1 (60-100 lb)	2.96	3.26	3.56	3.86
2 (100-165 lb)	2.25	2.50	2.75	3.00
3 (165-220 lb)	1.64	1.84	2.04	2.24
4 (220-260 lb)	1.12	1.32	1.52	1.72

Table 2. Lysine Content (%) of Experimental Diets

	0% Fat at Lys:Cal Ratios[a]				6% Fat at Lys:Cal Ratios			
Phase	1	2	3	4	1	2	3	4
1 (60-100 lb)	0.98	1.08	1.15	1.28	1.06	1.17	1.28	1.38
2 (100-165 lb)	0.75	0.83	0.90	1.00	0.81	0.90	0.99	1.08
3 (165-220 lb)	0.54	0.61	0.68	0.74	0.59	0.66	0.73	0.80
4 (220-260 lb)	0.37	0.44	0.51	0.57	0.40	0.48	0.55	0.62

[a]g lysine/Mcal mE.

Table 3. Influence of Increasing Lysine:Calorie Ratio and Dietary Fat Addition on Growth Performance and Carcass Characteristics of Growing-Finishing Gilts[a]

	0% Fat at Lys:Cal Ratios				6% Fat at Lys:Cal Ratios				Statistics P<				
Item	1	2	3	4	1	2	3	4	Fat	Lys:Cal	Fat × Lys:Cal	Linear	Quadratic
Phase 1 (d 0 to 25)													
ADG	1.45	1.44	1.55	1.59	1.61	1.60	1.67	1.63	.01	.03	.34	.01	.75
ADFI	3.20	3.03	3.11	3.20	3.08	3.00	2.98	2.92	.01	.08	.08	.18	.05
F/G	2.22	2.10	2.00	2.03	1.91	1.88	1.78	1.80	.01	.01	.63	.01	.12
Phase 2 (d 25 to 63)													
ADG	1.53	1.71	1.71	1.69	1.62	1.76	1.79	1.74	.03	.01	.95	.01	.01
ADFI	4.35	4.45	4.50	4.41	4.10	4.15	4.23	4.01	.01	.10	.72	.89	.02
F/G	2.85	2.60	2.64	2.64	2.53	2.36	2.36	2.30	.01	.01	.74	.01	.01
Phase 3 (d 63 to 93)													
ADG	1.58	1.56	1.61	1.71	1.51	1.67	1.69	1.71	.48	.05	.43	.02	.89
ADFI	5.66	5.39	5.29	5.44	4.95	5.10	5.12	4.95	.01	.68	.06	.24	.75
F/G	3.63	3.46	3.30	3.19	3.29	3.07	3.04	2.91	.01	.01	.85	.01	.51
Phase 4 (d 93 to 127)													
ADG	1.24	1.38	1.43	1.55	1.17	1.34	1.52	1.62	.84	.01	.58	.01	.63
ADFI	5.86	5.81	5.88	5.91	5.35	5.29	5.60	5.21	.01	.52	.87	.87	.53
F/G	4.76	4.23	4.14	3.86	4.66	4.12	3.63	3.30	.03	.01	.55	.01	.43
Overall (d 0 to 127)													
ADG	1.45	1.53	1.68	1.64	1.48	1.59	1.67	1.68	.01	.01	.75	.01	.08
ADFI	4.78	4.74	4.77	4.80	4.42	4.44	4.56	4.33	.01	.51	.29	.93	.37
F/G	3.30	3.09	2.96	2.88	2.99	2.79	2.73	2.64	.01	.01	.87	.01	.05
Final weight, lb	248.7	255.9	269.8	274.3	249.4	263.1	273.9	267.9	.10	.01	.77	.01	.13
Packing Plant Data[b]													
Carcass weight, lb	184.9	189.1	195.6	200.5	186.2	196.7	207.5	208.7					
Yield	75.7	75.8	75.8	76.1	75.8	75.9	75.0	75.6	.33	.57	.59	.98	.51
Back-fat depth, in	0.78	0.72	0.67	0.63	0.80	0.73	0.69	0.64	.17	.01	.97	.01	.32
Loin eye depth, in	2.21	2.25	2.35	2.35	2.17	2.24	2.35	2.37	.81	.01	.58	.01	.22
Percent lean	53.6	54.7	55.6	56.2	53.1	54.3	55.4	56.1	.14	.01	.87	.01	.16
Fat -free lean index	48.9	49.6	50.2	50.6	48.6	49.4	50.0	50.5	.12	.01	.98	.01	.25

[a]A total of 1,200 growing gilts (PIC) with an initial weight of 60 lb.
[b]Carcass weight was used as a covariate to analyze the packing plant data.

EFFECTS OF INCREASING LYSINE:CALORIE RATIO AND DIETARY FAT ADDITION ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF GROWING-FINISHING BARROWS[1]

M. De La Llata, S. S. Dritz[2], M. D. Tokach[3], R. D. Goodband, and J. L. Nelssen

Summary

A total of 1,200 growing-finishing barrows was used to determine the effects of increasing lysine:calorie ratio and dietary fat addition. Dietary treatments were arranged in a 2 × 4 factorial with two levels of fat (0 and 6%) and four lysine:calorie ratios in each of the four phases. The appropriate lysine: calorie ratios to maximize performance were: 3.01, 2.25 to 2.50, 1.78 to 1.98, and 1.42 to 1.62 from 75 to 130, 130 to 175, 175 to 220, and 220 to 260 lb, respectively. These ratios equate to approximate total lysine levels of 1.00, .80, 65 and .53%, respectively, in corn-soybean meal-based diets with no added fat.

(Key Words: Lysine:Calorie Ratio, Fat, Lysine, Finishing Pigs.)

Introduction

A lysine:calorie ratio can be used to determine the lysine requirement based on the dietary energy concentration. Determining an accurate lysine:calorie ratio will ensure that the right amount of lysine is provided in diets varying in energy density. Several studies have been conducted to determine the appropriate lysine:calorie ratio and the influence of fat additions to growing-finishing pig diets on growth performance and carcass characteristics. However, most of these trials have been conducted in university research settings, where the responses to fat addition have been much smaller than those observed in pigs reared under field conditions. The difference in the magnitude of these responses might be due to the fact that feed intake is normally 25 to 40% higher in university research settings than under commercial conditions. Therefore, the objective of this experiment was to determine the effects of added fat and different lysine:calorie ratios on growth performance and carcass characteristics of growing-finishing barrows reared under commercial conditions.

Procedures

A total of 1,200 growing barrows (PIC C22 × 337) with an initial weight of 75 lb was used in this experiment. Pigs were allotted to one of eight dietary treatments in a completely randomized design with 25 pigs/pen and six pens/treatment. The finishing barn was equipped with 48 totally slatted concrete pens. Each pen was equipped with a four-hole dry self-feeder (Staco) and one cup waterer. Pen dimensions were 10 ft × 18 ft, providing 7.2 sq ft/pig. The finishing facility is a doubled curtain-sided, deep pit barn and operates on manual ventilation during the summer and on automatic ventilation during the winter.

The corn soybean meal-based diets were arranged in a 2 × 4 factorial with two levels

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[2]Food Animal Health and Management Center.

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

of fat (0 and 6% choice white grease) and four lysine:calorie ratios in each phase. The four phases were 75 to 130, 130 to 175, 175 to 220, and 220 to 260 lb. Lysine:calorie ratios are shown in Table 1, and the corresponding lysine levels for each diet are shown in Table 2. Vitamin and trace mineral levels were similar to KSU recommendations, and all other nutrients met or exceeded the requirements estimates provided by NRC (1998).

Pigs weights by pen and feed disappearance were measured every 14 d to calculate ADG, ADFI, and F/G. Diet phase changes occurred every 28 d. At the termination of the study, pigs were sent to USDA-inspected packing plant for collection of individual carcass data. The pigs in each pen were marked with a different tattoo prior to marketing to allow carcass data to be attributed back to each pen. The experiment was conducted from August to December, 1998.

Analysis of variance was used to analyze the data as a completely randomized design with a 2 × 4 factorial treatment arrangement using GLM procedures of SAS with linear and quadratic polynomial contrasts.

Results and Discussion

During phase 1 (75 to 130 lb), increasing lysine:calorie ratio increased (quadratic, $P<.07$) ADG, and decreased (linear $P<.01$) F/G (Table 3). During phases 2, 3, and 4 and for the overall trial, increasing the lysine: calorie ratio linearly improved ($P<.01$) ADG and F/G. Although quadratic trends were not found except during phase 1, the responses during each period were greatest when the lysine:calorie ratio increased from the second to the third level, and the increase to the fourth level resulted in a further smaller response.

Adding 6% choice white grease to the diets increased ($P<.11$) ADG during phases 1 and 2 and for the overall experiment. Adding 6% fat to the diet decreased ($P<.02$) ADFI and improved ($P<.02$) F/G during all phases and for the overall trial.

Increasing the lysine:calorie ratio did not affect ($P>.65$) carcass yield. Back-fat depth, loin eye depth, percent lean, and fat-free lean index were improved (linear, $P<.01$) as the lysine:calorie ratio was increased. Adding 6% dietary fat tended to increase ($P<.08$) back-fat depth and decrease ($P<.08$) the fat-free lean index.

The results from this experiment suggest that adding 6% fat to the diets decreases F/G by approximately 9%. Similar to other experiments, adding fat to the diet improved ADG during the growing phases (75 to 175 lb), but not in the finishing phases (175 to 260 lb). Other research also demonstrates that adding fat only during phases 1, 2, and 3 would decrease the observed tendencies for reductions in percent lean and fat-free lean index.

These data also indicate that increasing the lysine:calorie ratio linearly improves growth performance; however, the greatest response was observed to the third lysine: calorie ratio and a small further response to the fourth level. According to this experiment, the appropriate lysine:calorie ratios to maximize growth performance of growing-finishing barrows are: 3.01, 2.25 to 2.50, 1.78 to 1.98, and 1.42 to 1.62 for phases 1, 2, 3, and 4, respectively. These ratios equate to an approximate total lysine levels of 1.00, .80, 65, and .53%, respectively, in corn-soybean meal-based diets with no added fat. The strong linear response observed in carcass parameters indicates that the lysine requirement to maximize carcass traits is higher than that to maximize growth performance.

Table 1. Lysine:Calorie Ratios

	Lys:Cal Ratio (g lys/Mcal ME)			
Phase	1	2	3	4
1 (75-130 lb)	2.41	2.71	3.01	3.31
2 (130-175 lb)	1.75	2.00	2.25	2.50
3 (175-220 lb)	1.38	1.58	1.78	1.98
4 (220-260 lb)	1.02	1.22	1.42	1.62

Table 2. Lysine Contents (%) of Experimental Diets

	0% Fat at Lys:Cal Ratios[a]				6% Fat at Lys:Cal Ratios			
Phase	1	2	3	4	1	2	3	4
1 (75-130 lb)	0.80	0.90	1.00	1.10	0.86	0.97	1.08	1.18
2 (130-175 lb)	0.58	0.67	0.75	0.83	0.63	0.72	0.81	0.90
3 (175-220 lb)	0.46	0.53	0.59	0.66	0.50	0.57	0.64	0.71
4 (220-260 lb)	0.34	0.41	0.47	0.54	0.37	0.44	0.51	0.59

[a]g lys/Mcal ME.

Table 3. Influence of Increasing Lysine:Calorie Ratio and Dietary Fat Addition on Growth Performance and Carcass Characteristics of Growing Finishing Barrows[a]

	0% Fat at Lys:Cal Ratios				6% Fat at Lys:Cal Ratios				Statistics P<				
Item	1	2	3	4	1	2	3	4	Fat	Lys:Cal	Fat × Lys:Cal	Linear	Quadratic
Phase 1 (d 0 to 32)													
ADG	1.59	1.63	1.66	1.67	1.59	1.71	1.75	1.70	.06	.04	.66	.02	.07
ADFI	3.91	3.84	3.75	3.81	3.68	3.74	3.80	3.58	.02	.53	.22	.19	.54
F/G	2.47	2.35	2.26	2.29	2.31	2.19	2.18	2.12	.01	.01	.72	.01	.10
Phase 2 (d 32 to 59)													
ADG	1.51	1.59	1.67	1.68	1.60	1.59	1.71	1.75	.11	.01	.76	.01	.91
ADFI	5.02	5.09	5.03	5.13	4.71	4.64	4.69	4.56	.01	.89	.45	.77	.88
F/G	3.34	3.20	3.02	3.06	2.94	2.93	2.76	2.60	.01	.01	.26	.01	.84
Phase 3 (d 59 to 85)													
ADG	1.60	1.59	1.75	1.73	1.53	1.51	1.77	1.80	.75	.01	.62	.01	.74
ADFI	5.95	6.03	6.12	6.04	6.68	5.40	5.47	5.31	.01	.44	.09	.29	.89
F/G	3.76	3.81	3.53	3.50	3.72	3.62	3.11	2.99	.02	.01	.24	.01	.80
Phase 4 (d 85 to 120)													
ADG	1.07	1.03	1.27	1.22	1.09	1.10	1.29	1.34	.22	.01	.82	.01	.80
ADFI	5.49	5.30	5.57	5.31	4.99	4.97	5.13	5.24	.01	.23	.20	.34	.84
F/G	5.16	5.18	4.45	4.37	4.70	4.58	4.06	3.94	.01	.01	.90	.01	.87
Overall (d 0 to 120)													
ADG	1.42	1.44	1.57	1.56	1.44	1.47	1.61	1.63	.04	.01	.69	.01	.54
ADFI	5.06	5.01	5.07	5.01	4.72	4.64	4.75	4.65	.01	.26	.97	.48	.80
F/G	3.56	3.47	3.24	3.21	3.29	3.17	2.95	2.85	.01	.01	.66	.01	.38
Live weight, lb	247.2	250.6	265.1	266.0	248.6	254.7	266.7	271.6	.21	.01	.92	.01	.71
Packing Plant Data[b]													
Carcass weight	187.5	193.8	197.1	204.0	189.6	203.6	209.2	211.7					
Yield	75.8	75.6	76.2	75.1	75.5	75.3	75.3	75.6	.38	.65	.25	.65	.71
Back-fat depth, in	0.92	0.85	0.77	0.74	0.93	0.86	0.82	0.78	.08	.01	.76	.01	.27
Loin eye depth, in	2.03	2.09	2.16	2.22	2.03	2.13	2.17	2.24	.47	.01	.91	.01	.74
Percent lean	50.8	52.1	53.4	54.1	50.6	51.9	52.7	53.5	.13	.01	.81	.01	.24
Fat-free lean index	47.3	48.1	49.0	49.4	47.1	47.9	48.4	48.9	.08	.01	.81	.01	.26

[a]A total of 1,200 growing barrows (PIC) with an initial weight of 75 lb.
[b]Carcass weight was used as a covariate to analyze the packing plant data.

PREDICTING LYSINE REQUIREMENTS USING PROTEIN AND LIPID ACCRETION CURVES FOR GROWING-FINISHING GILTS[1]

M. De La Llata, S. S. Dritz[2], M. D. Tokach[3], R. D. Goodband, and J. L. Nelssen

Summary

A total of 240 growing-finishing gilts (60 to 260 lb) was used to model accretion rates and the lysine:calorie ratio requirement based on lipid and protein growth. Real-time ultrasound measurements were used to estimate lipid and protein contents. These estimates then were translated into feed intake and lysine requirements. Gilts were fed one of eight different diet regimens, consisting of four increasing lysine:calorie ratios and two levels of fat (0 and 6%). Lipid and protein deposition rates could effectively model feed intake when pigs were fed lysine:calorie ratios close to their requirement. The modeled accretion rates effectively predicted the differences between treatments in agreement with the growth performance data. The modeled lysine:calorie ratio requirement accurately predicted the lysine:calorie ratios that maximized growth, evaluated by either the predicted or the actual data.

(Key Words: Real-Time Ultrasound, Lipid Accretion, Protein Accretion, Lysine:Calorie Ratio, Fat, Lysine, Finishing Pigs.)

Introduction

The estimation of on-farm protein and lipid accretion curves is a valuable tool to calculate the lysine requirement for growing-finishing pigs reared under specific environments. The daily energy intake can be calculated from the daily protein and lipid accretion estimates with an allowance for the maintenance energy requirement. The lysine requirement in grams per day divided by the daily energy intake results in an estimate of a lysine:calorie ratio. Using the ratio ensures that the right amount of lysine is provided in diets that vary in energy density. Several studies have been conducted to predict the lysine requirement from protein accretion estimations. However, the lysine:calorie ratios predicted from serial ultrasound estimates have not been compared to those estimated from conventional lysine titration experiments. Therefore, the objective of this study was to compare lysine:calorie ratio requirements modeled from real-time ultrasound data to requirements estimated by the more traditional lysine titration technique.

Procedures

A total of 240 gilts (PIC C22 × 337) with an initial weight of 60 lb was used in this experiment.

Treatments consisted of corn soybean meal-based diets (Table 1) arranged in a 2 × 4 factorial with two levels of fat (0 and 6% choice white grease) and four lysine:calorie ratios in each phase. More detailed descriptions of the diets, building characteristics, pen dimensions, and ventilation system are found in paper discussing growth performance results of this study (p. 88).

[1]Appreciation is expressed to Global Ventures for the use of pigs and facilities; to Pipestone Research Partners for partial financial support; and to Marty Heintz, Steve Rops, and Robert Powell for technical assistance.

[2]Food Animal Health and Management Center.

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

The 240 gilts used in the study were selected randomly from a total of 1,200 pigs that were housed in 48 pens at the rate of 25 pigs per pen. Five pigs/pen were selected, tagged, weighed, and scanned within 1 week of placement in the finishing barn and every 3 weeks after, until they were marketed at the end of the study.

The growth and real-time ultrasound data (backfat depth and loin eye area) were used to calculate daily body gain and lipid and protein accretion rates, based on the concepts developed by Dr. Allan Schinckel at Purdue University.

The daily lysine requirement in grams per day was calculated using the following formula:

$$\text{Total lysine g/day} = \frac{M + \frac{P \times L}{E}}{D}$$

Where M is the lysine needed for maintenance (.036 × Wt, $kg^{.75}$); *P* is the daily body protein accretion; L is the lysine content of body protein (6.6%); E is the postabsorptive efficiency of lysine utilization (60%); and D is the true digestibility of lysine in the diet (88%).

Predicted daily feed intake was calculated by dividing the metabolizable energy requirement by the energy content of the diet. The metabolizable energy required to drive the observed protein and lipid accretion (with an allowance for the maintenance energy requirement) was calculated using the following formula:

Metabolizable energy requirement = (.255 × weight in $kg^{.60}$) + (8.84 × protein accretion) + (11.4 × lipid accretion)

The lysine:calorie ratio requirement was calculated by dividing the requirement of total lysine in grams/day by the requirement of metabolizable energy in Mcal/day.

Results and Discussion

The modeled ADG is presented in Figure 1. Average daily gain was predicted to be greater for the third and fourth lysine:calorie ratios (treatments C,G and D,H) than for the lower lysine:calorie ratios. Also, adding fat to the diets resulted in improved predicted gains within each lysine:calorie ratio. These results agree with the growth performance data (p. 88). The ADG was increased by increasing the lysine:calorie ratio and by adding fat to the diets during phases 1 and 2 and for the overall trial.

Protein and lipid accretion rates (Figures 2 and 3) were greater for treatments C,G and D,H (third and four lysine:calorie ratios). The increase in protein accretion rate for the third and fourth lysine:calorie ratios compared to the first and second was greater than the increase in lipid accretion. In other words, treatments C,G and D,H, deposited more protein in relation to fat than treatments A,E and B,F (first and second lysine:calorie ratios). These results were reflected in the carcass composition analysis (p. 88). Percent lean and fat-free lean index were increased and backfat was decreased with increasing lysine:calorie ratio.

Adding fat to the diets did not appear to influence protein accretion (Figure 2). However, a tendency for greater lipid accretion (Figure 3) can be detected within each lysine:calorie ratio for diets containing fat. Again, this agrees with the carcass composition results.

The increased ADG and protein accretion (Figures 1 and 2) observed for treatment H (highest lysine level fed) during phases 3 and 4 suggest that the actual requirement was close to or above the ratio fed. This conclusion agrees with the linear response observed for ADG during phases 3 and 4 (p. 88).

Predicted ADFI was similar for all treatments at the beginning of the growing period (Figure 4), with a slight intake advantage for treatments with no added fat. After approximately 170 lb, predicted ADFI for treatments A and B decreased, and for the overall period, ADFI followed lipid and protein accretion rates, with treatments C,G, and D,H (third and fourth lysine:calorie ratios) showing the highest predicted intake. However,

the growth performance data (p. 88) did not show decreases in feed intake for treatments A and B. In contrast, ADFI for treatments A and B was higher than that of treatments G and H and similar to that of treatments C and D. This means that based on the actual intake data, feed intake was driven mainly by the energy content of the diet and the weight of the pig, rather than by the lysine content of the diet or by the lipid and protein accretion rates. This implies that the formulas to calculate feed intake based on lipid and protein deposition are more accurate when pigs are fed close to their requirement. When pigs are fed lysine levels below their requirement, the formulas underestimate feed intake.

The modeled lysine requirement in g/day (Figure 5) followed protein accretion. The greatest lysine requirement was predicted for treatments C,G and D,H (third and four lysine:calorie ratios).

The predicted lysine:calorie ratio requirements for the different treatments are presented in Figure 6. The treatments with greater protein accretion and, thus, with greater requirements for total lysine (C,G and D,H) also demonstrated an increased lysine: calorie ratio requirement in comparison to treatments A,E and B,F. These results agree with the lysine:calorie ratios fed during the growth performance experiment (p. 88), where treatments C,G and D,H corresponded to the highest lysine:calorie ratios fed.

Treatment D was selected to compare the predicted lysine:calorie ratio vs. the actual requirement observed in the growth performance experiment (companion paper). This comparison is presented in Figure 7. The modeled lysine:calorie ratio requirement accurately predicted the actual lysine:calorie ratio requirement observed in the growth performance experiment. In both cases (predicted and actual), treatment D (fourth lysine:calorie ratio) increased growth performance when compared to treatments A,E and B,F (first and second lysine:calorie ratios).

In summary, real-time ultrasound can be used to accurately predict growth and the lysine:calorie ratio requirement of growing–finishing gilts reared in specific environments. Also, it can be used to model feed intake based on lipid and protein depositions. However, the formulas to calculate feed intake appear to be more accurate when pigs are fed close to their requirement. This implies that when lysine requirements derived using ultrasound measurements are in excess of the dietary levels fed, the requirement may actually be higher than the modeled estimate.

Table 1. Dietary Treatments

	Lysine:Calorie Ratio (g lysine/Mcal ME)							
	0% Fat				6% Fat			
Item	A	B	C	D	E	F	G	H
Phase 1 (60-100 lb)	2.96	3.26	3.56	3.86	2.96	3.26	3.56	3.86
Phase 2 (100-165 lb)	2.25	2.50	2.75	3.00	2.25	2.50	2.75	3.00
Phase 3 (165-220 lb)	1.64	1.84	2.04	2.24	1.64	1.84	2.04	2.24
Phase 4 (220-260 lb)	1.12	1.32	1.52	1.72	1.12	1.32	1.52	1.72

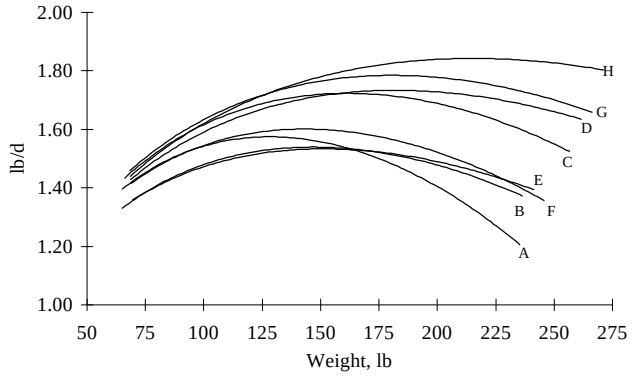


Figure 1. Modeled Daily Growth for Gilts Fed Diets with Increasing Lysine:Calorie Ratios and Two Dietary Fat Levels.

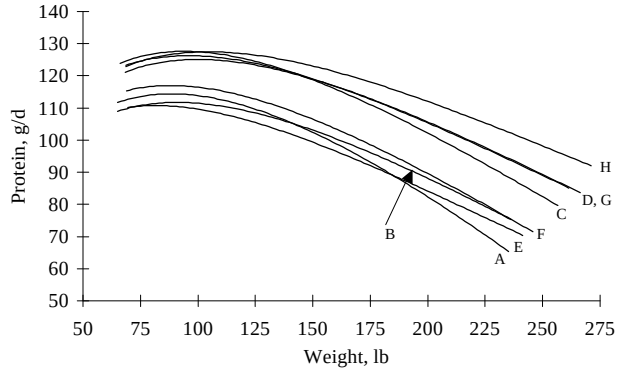


Figure 2. Modeled Daily Protein Accretion for Gilts Fed Diets with Increasing Lysine: Calorie Ratios and Two Dietary Fat Levels.

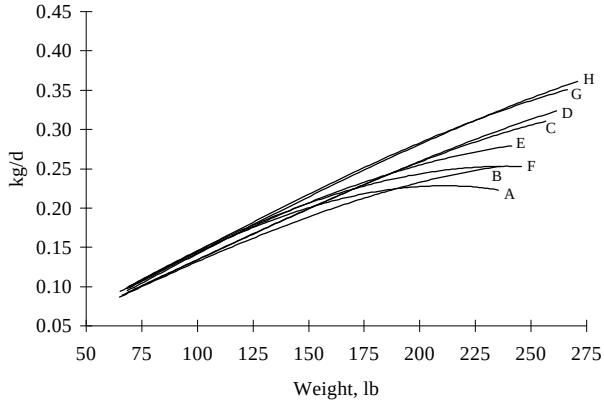


Figure 3. Modeled Daily Lipid Accretion for Gilts Fed Diets with Increasing Lysine: Calorie Ratios and Two Dietary Fat Levels.

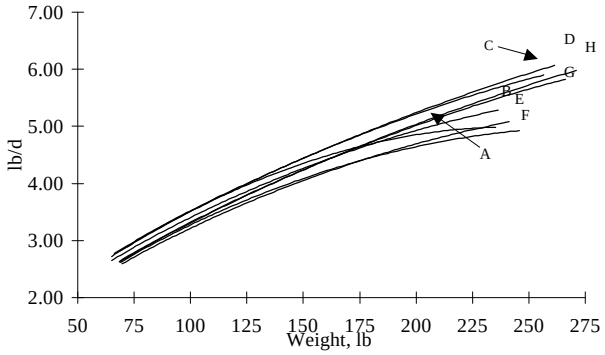


Figure 4. Modeled Daily Feed Intake for Gilts Fed Diets with Increasing Lysine: Calorie Ratios and Two Dietary Fat Levels.

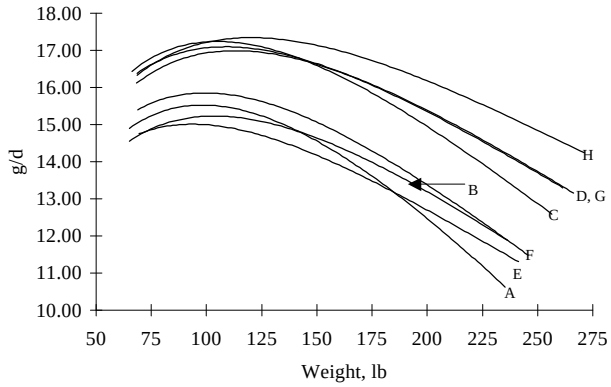


Figure 5. Predicted Daily Total Lysine Requirement for Gilts Fed Diets with Increasing Lysine:Calorie Ratios and Two Dietary Fat Levels.

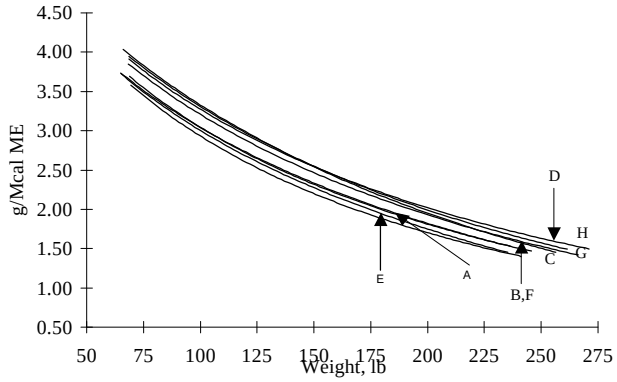


Figure 6. Predicted Lysine: Calorie Ratio Requirement for Gilts Fed Diets with Increasing Lysine:Calorie Ratios and Two Dietary Fat Levels.

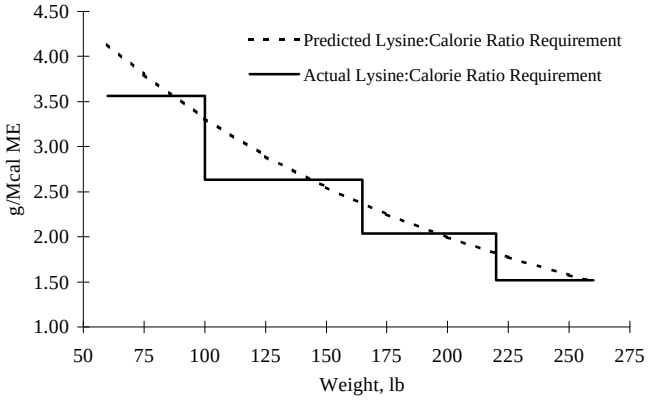


Figure 7. Comparison Between Predicted and Actual Lysine:Calorie Ratio Requirements for Growing-Finishing Gilts.

Swine Day 1999

PREDICTING LYSINE REQUIREMENTS USING PROTEIN AND LIPID ACCRETION CURVES FOR GROWING-FINISHING BARROWS[1]

M. De La Llata, S. S. Dritz[2], M. D. Tokach[3], R. D. Goodband, and J. L. Nelssen

Summary

A total of 240 growing-finishing barrows (75 to 260 lb) were used to model accretion rates and the lysine:calorie ratio requirement based on lipid and protein content data obtained with a real-time ultrasound. Barrows were fed eight different diets consisting of four increasing lysine:calorie ratios and two levels of fat (0 and 6%). The modeled accretion rates effectively predicted the differences between treatments in agreement with the actual data. The modeled lysine:calorie ratio requirement accurately predicted the lysine:calorie ratios that maximized growth, evaluated by either the predicted or the actual data. Lipid and protein deposition rates were used to effectively model feed intake when pigs were fed close to their requirement.

(Key Words: Real-Time Ultrasound, Lipid Accretion, Protein Accretion, Lysine:Calorie Ratio, Fat, Lysine, Finishing Pigs.)

Introduction

The estimation of on-farm protein and lipid accretion curves is a valuable tool to calculate the lysine requirement for growing-finishing pigs reared under specific environments. The daily energy intake can be calculated from the daily protein and lipid accretion estimates with an allowance for the maintenance energy requirement. The lysine requirement in grams per day divided by the daily energy intake results in an estimate of a lysine:calorie ratio to use in diet formulation. Several studies have been conducted to predict the lysine requirement from protein accretion estimations. However, the lysine:calorie ratios predicted from serial ultrasound estimates have not been compared to those estimated from conventional lysine titration experiments. Therefore, the objectives of this study were to model the lysine:calorie ratio requirement using real-time ultrasound data for growing-finishing barrows reared under commercial settings and to compare those estimates to values determined on the same group of barrows using the more traditional lysine titration technique.

Procedures

A total of 240 barrows (PIC C22 × 337) with an initial weight of 75 lb was used in this experiment.

Treatments consisted of corn soybean meal-based diets (Table 1) arranged in a 2 x 4 factorial with two levels of fat (0 and 6% choice white grease) and four lysine:calorie ratios in each phase. More detailed descriptions of the diets, building characteristics, pen dimensions, and ventilation system are found in the paper discussing growth performance results of this study (p. 92).

[1]Appreciation is expressed to Global Ventures for the use of pigs and facilities; to Pipestone Research Partners for partial financial support; and to Marty Heintz, Steve Rops, and Robert Powell for technical assistance.

[2]Food Animal Health and Management Center.

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

The 240 barrows used in the study were selected randomly from a total of 1,200 pigs that were housed in 48 pens at the rate of 25 pigs per pen. Five pigs/pen were selected, tagged, weighed, and scanned within 1 week of placement in the finishing barn and every 3 weeks after, until they were marketed at the end of the study.

The growth and real-time ultrasound data (backfat depth and loin eye area) were used to calculate daily body gain and lipid and protein accretion rates, based on the concepts developed by Dr. Allan Schinckel at Purdue University.

The daily lysine requirement in grams per day was calculated using the following formula:

$$\text{Total Lysine g/day} = \frac{M + \frac{P \times L}{E}}{D}$$

Where M is the lysine needed for maintenance (.036 × Wt, $kg^{.75}$); *P* is the daily body protein accretion; L is the lysine content of body protein (6.6%); E is the postabsorptive efficiency of lysine utilization (60%); and D is the true digestibility of lysine in the diet (88%).

Predicted daily feed intake was calculated by dividing the metabolizable energy requirement by the energy content of the diet. The metabolizable energy required to drive the observed protein and lipid accretion (with an allowance for the maintenance energy requirement) was calculated using the following formula:

Metabolizable energy requirement = (.255 × weight in $kg^{.60}$) + (8.84 × protein accretion) + (11.4 × lipid accretion)

The lysine:calorie ratio requirement was calculated by dividing the requirement of total lysine in grams/day by the requirement of metabolizable energy in Mcal/day.

Results and Discussion

The modeled ADG is presented in Figure 1. Average daily gain was predicted to be greater for the third and fourth lysine:calorie ratios (treatments C,G, and D,H) than for the first and second lysine:calorie ratios (treatments A,E and B,F). Adding fat to the diets resulted in improved predicted gains within each lysine:calorie ratio. These results agree with the modeled ADG and the growth performance data for barrows (p. 92). The ADG was increased by increasing the lysine:calorie ratio and by adding fat to the diets during phases 1 and 2 and for the overall trial.

Modeled protein accretion rate (Figure 2) was greater for treatments C,G and D,H (third and four lysine:calorie ratios) compared to the first and second lysine:calorie ratios (treatments A,E and B,F).

Modeled lipid accretion rate (Figure 3) was greater for treatments G and H (third and fourth lysine:calorie ratios with added fat) followed by the rest of the treatments except for treatment B (second lysine:calorie ratio with no added fat), which presented the lowest modeled lipid accretion. Treatments E and F were expected to have higher fat accretion than treatments A and B. This held true except that treatments A and E has similar predicted fat accretion. However, in both experiments, treatments C,G and D,H (third and fourth lysine:calorie ratios) deposited more protein in relation to fat than treatments A,E and B,F (first and second lysine: calorie ratios). These results are supported by the carcass composition analysis presented in the growth performance paper (p. 92). Percent lean and fat-free lean index were increased and backfat was decreased with increasing lysine:calorie ratios.

Adding fat to the diets did not appear to have a great influence on protein accretion (Figure 2). However, a tendency for greater lipid accretion (Figure 3) can be detected, particularly in treatments F, G, and H (second, third, and fourth lysine:calorie ratios with added fat) Again, this agrees with the carcass composition results.

Until approximately 160 lb, predicted ADFI (Figure 4) was similar for all treatments, with a slight intake advantage for treatments with no added fat. This agrees with the measured performance in this study. After 160 lb, predicted ADFI decreased for treatments A, B, E, and F compared to the other treatments. These treatments were furthest below the pigs requirements. In contrast, the growth performance data did not show decreases in feed intake for these treatments. This indicates (based on the field data) that feed intake was driven mainly by the energy content of the diet and weight of the pig, rather than by the lysine content of the diet or by the lipid and protein accretion rates. The formulas to calculate feed intake based on lipid and protein deposition appear to be more accurate when pigs are fed close to their requirement.

The modeled lysine requirement in g/day (Figure 5) followed protein accretion. As expected, the greatest lysine requirement was predicted for treatments C,G and D,H (third and four lysine:calorie ratios).

Treatments with greater protein accretion (C,G and D,H,) and thus, with a greater requirement for total lysine, also demonstrated an increased lysine:calorie ratio requirement (Figure 6) when compared to treatments A,E and B,F. These results agree with the lysine:calorie ratios fed during the growth performance experiment (p. 92), where treatments C,G and D,H corresponded to the highest lysine:calorie ratio regimens fed. Also, these data agree with the responses observed with gilts (companion papers).

In order to compare the predicted lysine:calorie ratio requirement vs. the actual ratio fed (p. 92), treatment D was selected (Figure 7). During phases 1 and 2 (75 to 175 lb), the modeled lysine:calorie ratio requirement was higher at the beginning of the phase but similar at the end of phase. During phases 3 and 4 (175 to 260 lb), the modeled lysine:calorie ratio requirement accurately predicted the actual lysine:calorie ratio requirement observed. The reason for the difference between the predicted and the actual lysine:calorie ratio requirement during phases 1 and 2 was due to the fact that treatment D had a greater predicted lysine:calorie ratio requirement during these first phases compared to the same lysine:calorie ratio regimen but with added fat. This is surprising, because we would expect the modeled prediction requirement for the same lysine: calorie ratio to be similar. On the other hand, the actual lysine:calorie ratio requirement used for this comparison was based on the greatest numerical response observed in the growth performance data, which was for the third lysine:calorie ratio in phase 1 and between the third and fourth lysine:calorie ratios in the rest of the phases. However, statistically, a significant linear response was observed in the growth performance data. This means that we could have chosen the fourth lysine:calorie ratio regimen as the actual requirement observed, which would have agreed more with the predicted requirement.

In conclusion, this study demonstrated that real-time ultrasound can be used to accurately predict growth and lysine:calorie ratio requirement of growing–finishing pigs reared in specific environments. Also, it can be used to model feed intake based on lipid and protein depositions. However, the formulas to calculate feed intake appear to be more accurate when pigs are fed close to their requirement, which implies that when lysine requirements derived using ultrasound measurements are in excess of the dietary levels fed, the requirement may actually be higher than the modeled estimate.

Table 1. Dietary Treatments

		Lysine:Calorie Ratio (g lysine/Mcal ME)							
		0% Fat				6% Fat			
Item		A	B	C	D	A	B	C	D
Phase 1	(75-130 lb)	2.41	2.71	3.01	3.31	2.41	2.71	3.01	3.31
Phase 2	(130-175 lb)	1.75	2.00	2.25	2.50	1.75	2.00	2.25	2.50
Phase 3	(175-220 lb)	1.38	1.58	1.78	1.98	1.38	1.58	1.78	1.98
Phase 4	(220-260 lb)	1.02	1.22	1.42	1.62	1.02	1.22	1.42	1.62

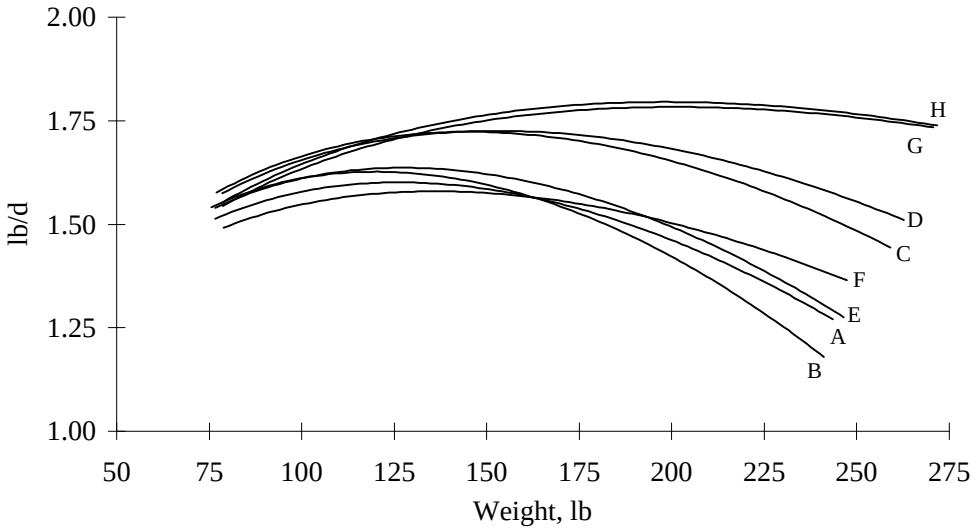


Figure 1. Modeled Growth for Barrows Fed Diets with Increasing Lysine:Calorie Rations and Two Dietary Fat Levels.

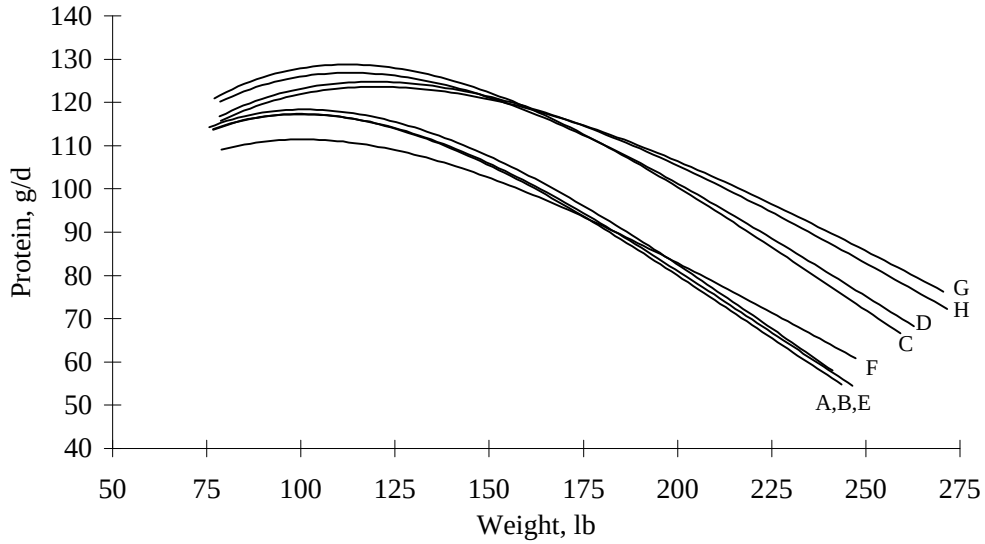


Figure 2. Modeled Protein Accretion for Barrows Fed Diets with Increasing Lysine:Calorie Rations and Two Dietary Fat Levels.

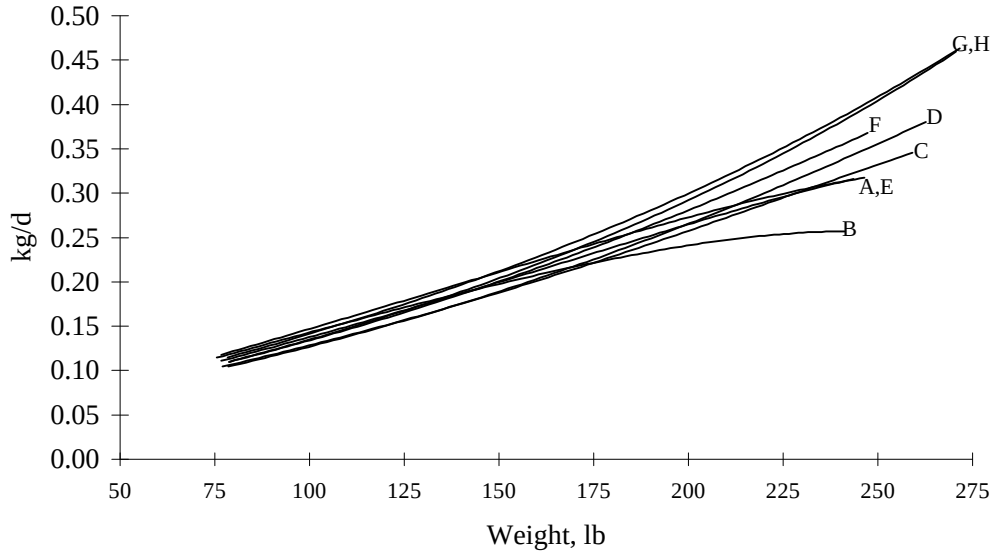


Figure 3. Modeled Lipid Accretion for Barrows Fed Diets with Increasing Lysine:Calorie Rations and Two Dietary Fat Levels.

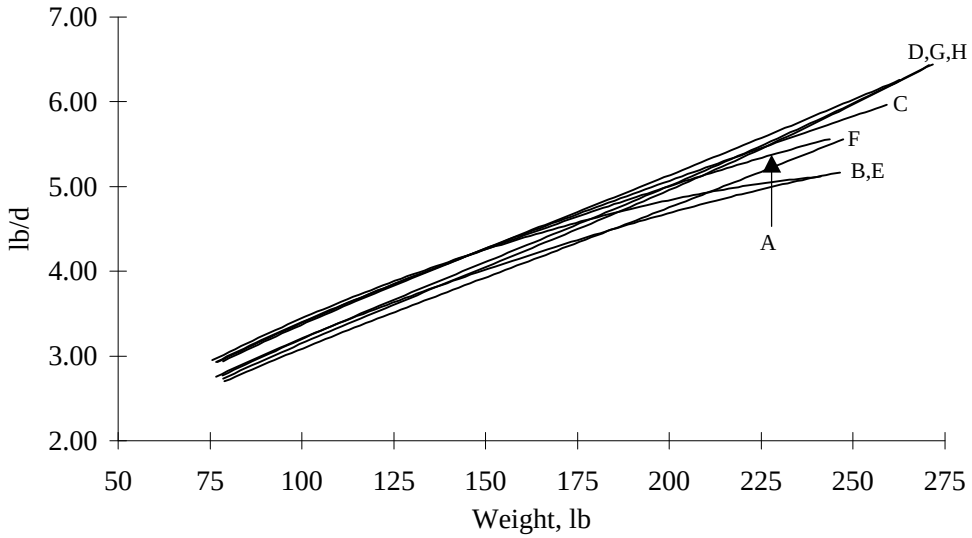


Figure 4. Modeled Daily Feed Intake for Barrows Fed Diets with Increasing Lysine:Calorie Rations and Two Dietary Fat Levels.

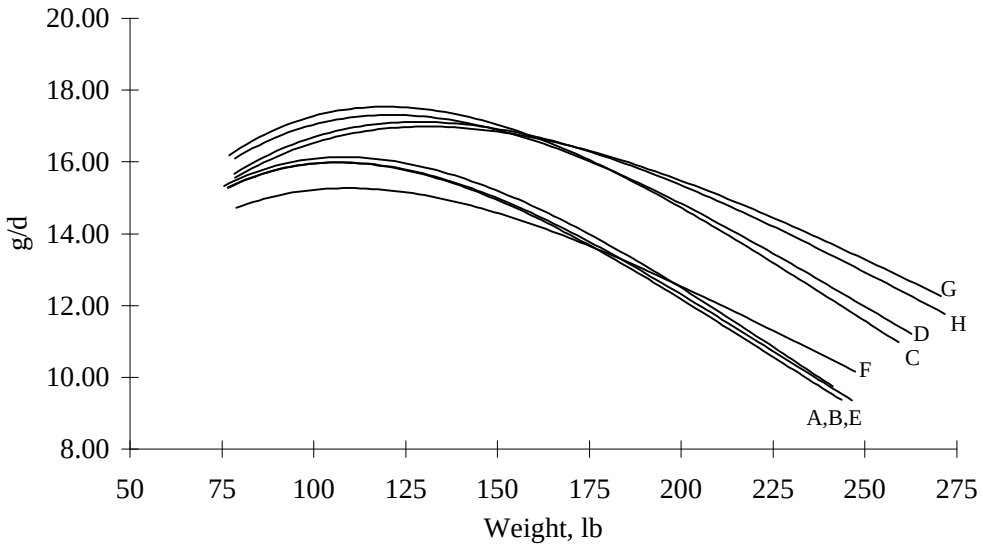


Figure 5. Predicted Daily Total Lysine Requirement for Barrows Fed Diets with Increasing Lysine:Calorie Rations and Two Dietary Fat Levels.

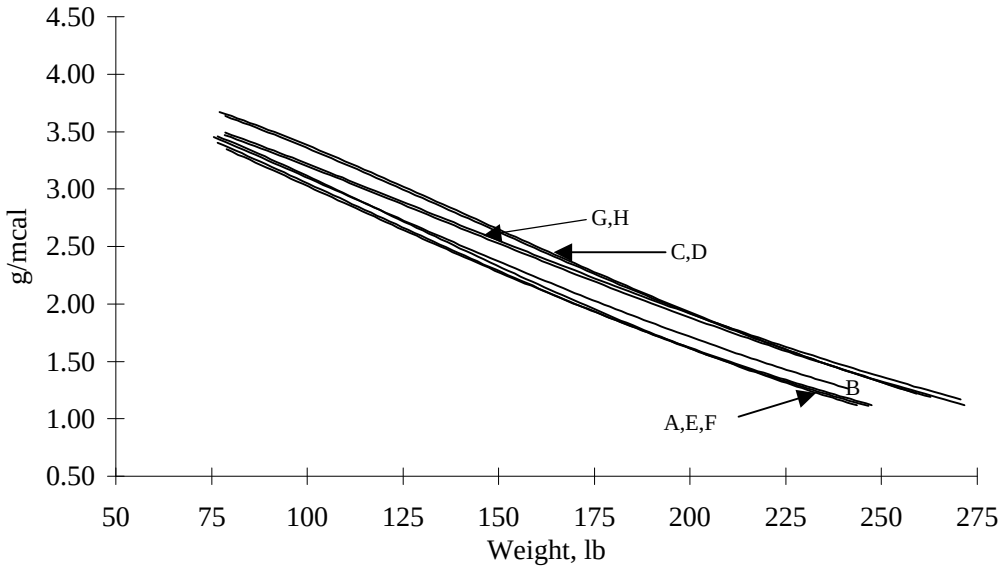
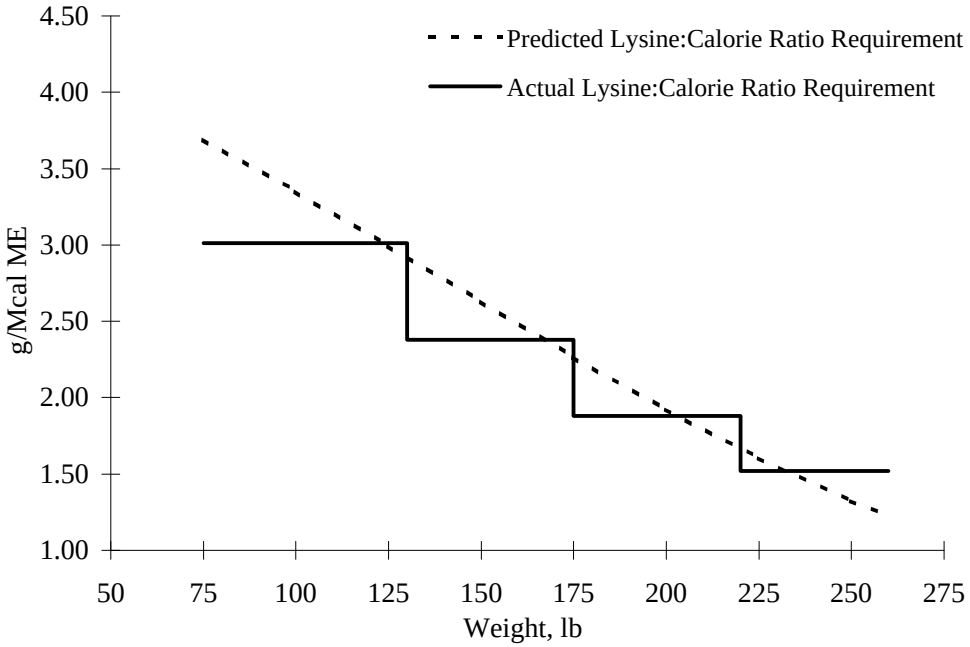


Figure 6. Predicted Lysine:Calorie Ratio Requirement for Barrows fed Diets with Increasing Lysine:Calorie Rations and Two Dietary Fat Levels.

Figure 7. Comparison between Predicted and ActualLysine:Calorie Ratio Requirements for Growing-Finishing Barrows.



Swine Day 1999

EFFECTS OF ADDING AND REMOVING DIETARY FAT ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF GROWING-FINISHING PIGS[1]

M. De La Llata, S. S. Dritz[2], M. D. Tokach[3], R. D. Goodband, and, J. L. Nelssen

Summary

We conducted an experiment using 1,050 growing-finishing pigs to determine the carryover effect of adding and removing fat in diets. The experimental treatments consisted of six different sequence arrangements of diets without fat or with 6% added fat. Diets were fed in four phases. During each phase, ADFI and F/G were decreased when fat was added to the diets. Fat inclusion in the diet during one phase had no influence on the response to fat addition during another phase. Back-fat depth was increased and fat-free lean index decreased when fat was added to the diet during all phases, but not when fat was added to the diet during phases 1, 2, and/or 3.

(Key Words: Dietary Fat, Subsequent Performance, Finishing Pigs.)

Introduction

The inclusion of fat and level added to growing-finishing diets are determined by the price of the fat source and by the design of the particular production system. Recent data have indicated a linear improvement in feed efficiency through the growing and finishing phases with increasing additions of fat to the diets. In general, feed efficiency is expected to improve 2% for every percent of added fat.

Based on these results, the addition of fat is recommended whenever it is economical. Therefore, fat could be added or removed from pig diets at different stages of growth based on economics. However, the carryover effect of removing fat from the diet has not been evaluated. Thus, the objective of this study is to determine the carryover effects of removing fat from the diet on growth performance and carcass characteristics of finishing pigs reared in a commercial environment.

Procedures

A total of 525 barrows and 525 gilts (PIC C22 × 337) with an initial weight of 55 lb was used in this experiment. Barrows and gilts were penned separately as they entered the finishing building from the nursery. Pigs were blocked by gender and weight and allotted to one of six dietary treatments in a randomized block design. Pigs were housed in totally slatted concrete pens with 25 pigs/pen and six pens/treatment. Each pen was equipped with a four-hole dry self-feeder (Staco) and one cup waterer. Pen dimensions were 10 ft × 18 ft, providing 7.2 sq ft/pig. The finishing facility is a doubled curtain-sided, deep pit barn and operates on manual ventilation during the summer and on automatic ventilation during the winter.

The corn-soybean meal-based diets (Table 1) without fat or with 6% choice white grease were fed in four phases. The

[1]Appreciation is expressed to Global Ventures for the use of pigs and facilities; to Pipestone Research Partners for partial financial support; and to Marty Heintz, Steve Rops, and Robert Powell for technical assistance.

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treatments consisted of six different sequence arrangements of the diets across the four phases (Table 2). The four phases were 55 to 100 lb, 100 to 150 lb, 150 to 200 lb, and 200 to 250 lb. The lysine:calorie ratios of the diets were 3.72, 3.17, 2.42, and 1.90 g lysine/Mcal ME, for phases 1, 2, 3, and 4, respectively. Vitamin and trace mineral levels were similar to KSU recommendations, and all other nutrients met or exceeded the requirements estimates provided by NRC (1998).

Pigs weights by pen and feed disappearance were measured every 14 d to calculate ADG, ADFI, and F/G. Diet phase changes occurred every 28 d. At the termination of the study, pigs were sent to USDA-inspected packing plant for collection of individual carcass data. The pigs in each pen were marked with a different tattoo prior to marketing to allow carcass data to be attributed back to each pen. The experiment was conducted from March to July 1999.

Analysis of variance was used to analyze the data as a randomized block design using GLM procedures of SAS with multiple comparison contrasts for growth performance in all phases, and with least square mean comparisons for the overall and carcass composition data.

Results and Discussion

During phase 1, ADG was not affected ($P>.84$) by dietary treatments (Table 3). Diets containing 6% added fat decreased ($P<.001$) ADFI and F/G compared to the diets not containing added fat.

In phase 2, adding 6% fat to the diet increased ($P<.002$) ADG, decreased ($P<.001$) F/G, and tended to decrease ($P<.12$) ADFI compared to diets without added fat.

During phase 3, ADG was not affected ($P>.32$) by dietary treatment. Pigs fed diets containing added fat had lower ($P<.02$) ADFI and F/G when compared to pigs fed diets without added fat.

During phase 4, ADG was not affected ($P>.53$) by dietary treatments. Feeding diets containing 6% choice white grease decreased ($P<.02$) ADFI and F/G compared to feeding diets without added fat.

For the overall experiment, ADG was not affected ($P>.44$) by dietary treatment. The treatment with 6% added fat during all four phases had the lowest ($P<.05$) ADFI. Pigs fed diets containing 6% added fat during phases 1 and 2 or phases 1, 2, and 3 had intermediate feed intake. Pigs that were fed diets containing added fat for the shortest amount of time had the highest feed intake. The response in overall F/G reflected the duration that fat was fed in the diet. Pigs with the lowest F/G were fed diets containing added fat for all phases or at least the first three phases. Pigs fed diets with fat added only during phase 1 or not at all had the poorest F/G.

No differences ($P>.65$) were observed in carcass yield among the dietary treatments. Back-fat depth was increased ($P<.05$) and fat-free lean index decreased ($P<.05$) for the dietary treatments containing 6% added fat in all phases. No differences ($P>.50$) in back-fat depth or fat-free lean index were observed among the rest of the treatments.

The results from this experiment indicate that adding and removing dietary fat during different phases of growth had no carryover effects. These data suggest that when inclusion of choice white grease in the diet is economical, it should be used during the first three phases (up to 200 lb) and then removed. This will achieve similar growth performance but better carcass characteristics than those resulting from adding fat during all phases.

Table 1. Diet Compositions

	Phase 1		Phase 2		Phase 3		Phase 4	
Ingredient, %	0% Fat	6% Fat	0% Fat	6% Fat	0% Fat	6% Fat	0% Fat	6% Fat
Corn	61.86	52.00	68.47	59.05	77.67	69.05	83.88	75.96
Soybean meal, 46.5%	35.24	39.13	28.70	32.18	19.62	22.26	13.51	15.43
Choice white grease	0	6.0	0	6.0	0	6.0	0	6.0
Monocal. phos., 21% P	1.30	1.28	1.25	1.20	1.20	1.20	1.13	1.13
Limestone	1.03	1.03	1.00	1.00	1.00	.98	.98	.98
Salt	.35	.35	.35	.35	.35	.35	.35	.35
Vitamin premix	.08	.08	.08	.08	.06	.06	.06	.06
Trace mineral premix	.15	.15	.15	.15	.10	.10	.10	.10
Calculated Analysis								
Lysine, %	1.23	1.33	1.05	1.14	.81	.87	.63	.68
Met & cys:lysine ratio, %	59	56	62	58	69	65	78	72
Threonine:lysine ratio, %	68	66	69	67	73	70	78	74
Tryptophan:lysine ratio, %	22	21	22	21	22	21	22	21
Calcium, %	.77	.77	.73	.73	.69	.69	.65	.65
Available phosphorus, %	.35	.35	.33	.33	.31	.31	.29	.29
Lysine:calorie ratio, g/mcal	3.72	3.72	3.17	3.17	2.42	2.42	1.90	1.90

Table 2. Sequence Arrangements of Treatments

	Sequence of Treatments (% Fat Level)					
Phase	A	B	C	D	E	F
1 (55-100 lb)	0	6	6	6	6	0
2 (100-150 lb)	0	6	0	6	6	6
3 (150-200 lb)	0	6	0	0	6	0
4 (200-250 lb)	0	6	0	0	0	6

Table 3. Influence of Adding and Removing Dietary Fat on Growth Performance and Carcass Characteristics of Growing-Finishing Pigs[e]

	Dietary Fat							
Phase 1	0	6	6	6	6	0		
Phase 2	0	6	0	6	6	6		
Phase 3	0	6	0	0	6	0	Added Fat *vs.*	
Phase 4	0	6	0	0	0	6	No Added Fat	
Item							P <	CV, %
Phase I (d 0 to 31)								
ADG	1.52	1.51	1.57	1.53	1.56	1.56	0.912	8.88
ADFI	3.22	2.91	2.98	2.93	2.92	3.32	0.001	7.56
F/G	2.14	1.93	1.90	1.92	1.88	2.13	0.001	5.33
Phase II (d 31 to 58)								
ADG	1.65	1.74	1.65	1.85	1.77	1.96	0.002	9.03
ADFI	4.03	3.74	4.00	3.86	3.62	4.09	0.126	9.31
F/G	2.45	2.15	2.43	2.09	2.04	2.11	0.001	6.84
Phase III (d 58 to 86)								
ADG	1.75	1.82	1.76	1.66	1.70	1.70	0.378	9.58
ADFI	5.21	4.83	5.45	5.06	4.81	5.12	0.002	6.68
F/G	2.99	2.70	3.09	3.08	2.83	3.01	0.003	8.65
Phase IV (d 86 to 121)								
ADG	1.85	1.92	1.80	1.75	1.80	1.85	0.237	11.34
ADFI	5.99	5.54	6.14	6.01	5.89	5.73	0.001	3.98
F/G	3.26	2.90	3.45	3.55	3.28	3.10	0.013	13.07
Overall (d 0 to 121)								
ADG	1.68	1.75	1.70	1.69	1.73	1.77		6.02
ADFI	4.61[a]	4.28[b]	4.66[a]	4.50[ab]	4.39[ab]	4.59[a]		5.35
F/G	2.74[a]	2.45[b]	2.75[a]	2.66[ac]	2.54[bc]	2.61[c]		4.39
Carcass Data[d]								
Live weight, lb	258.3	266.4	262.2	263.0	261.4	263.2		5.25
Carcass yield, %	76.2	76.7	72.9	74.2	76.8	76.5		4.50
Loin eye depth, in	2.21[ab]	2.24[ab]	2.22[ab]	2.20[b]	2.19[b]	2.29[a]		2.86
Back-fat depth, in	0.75[a]	0.81[b]	0.76[a]	0.74[a]	0.76[a]	0.77[a]		4.68
Lean, %	54.0[a]	53.2[b]	53.9[a]	54.1[a]	53.8[a]	53.9[a]		1.03
Fat-free lean index	49.4[a]	48.6[b]	49.3[a]	49.5[a]	49.3[a]	49.1[a]		0.89

[a,b,c]Means in the same row with different superscript differ P<.05.

[d]Carcass weight used as a covariate to analyze the packing plant data.

[e]A total of 1,050 growing pigs with an initial weight of 55 lb.

ECONOMICS OF ADDING FAT AND INCREASING LYSINE:CALORIE RATIO IN DIETS FOR GROWING-FINISHING GILTS[1]

M. De La Llata, M. Langemeier[2], S. S. Dritz[3], M. D. Tokach[4], R. D. Goodband, and J. L. Nelssen

Summary

A total of 1,200 gilts was used to evaluate the economics of adding fat and increasing lysine:calorie ratio in diets for growing-finishing pigs. Diets were fed in four phases and consisted of a 2 × 4 factorial arrangement with two levels of fat (0 and 6%) and four increasing lysine:calorie ratios. Eight economic scenarios combining corn, soybean meal, fat, and hog prices with two packer grading systems were created. Stochastic dominance analysis was performed on 64 alternatives (8 treatments × 8 scenarios). The third and fourth (higher) lysine: calorie ratios increased income over feed cost when fat was added to the diets, except for the high fat price scenario in which the fourth lysine:calorie ratio without added fat dominated. The first two (lower) lysine: calorie ratios were inferior under all scenarios.

(Key Words: Lysine:Calorie Ratio, Fat, Lysine, Finishing Pigs. Economics.)

Introduction

Several experiments have demonstrated that added dietary fat increases ADG during the growing phase and decreases ADFI and F/G during the growing-finishing phase. Studies also are shown that dietary amino acid levels need to be increased in concert with increases in energy content of the diet.

Adding fat to the diets and supplementing additional dietary amino acids will increase the cost of the diets. Therefore, economics should dictate the inclusion of fat in diets for growing-finishing pigs. In other words, the extra income received for improved performance must be greater than the increase in dietary cost.

Thus, the objectives of this study were to evaluate if adding fat is cost-effective and to determine the appropriate lysine:calorie ratio based on income over feed cost in diets for growing-finishing pigs reared under commercial settings.

Procedures

A total of 1,200 gilts (PIC C22 × 337) with an initial weight of 60 lb was used in this study. Pigs were allotted to one of eight dietary treatments with 25 pigs/pen and six pens/treatment. The building characteristics, pen dimensions, and ventilation system are described in the paper discussing growth performance results of this study (p. 88).

The corn soybean meal-based diets were arranged in a 2 × 4 factorial with two levels of fat (0 and 6% choice white grease) and four lysine:calorie ratios in each of the four phases (Table 1). A more detailed description of the diets is provided in the growth performance paper (p. 88).

[1]Appreciation is expresssed to Global Ventures for the use of pigs and facilities; to Pipestone Research Partners for partial financial support; and to Marty Heintz, Steve Rops, and Robert Powell for technical assistance.

[2]Department of Agricultural Economics.

[3]Food Animal Health and Management Center.

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

Diet phase changes occurred every 28 d. At the end of phase 4, all pigs were sent to a USDA-inspected packing plant for individual carcass data collection.

Income over feed cost was calculated by subtracting the feed cost from the gross income for each treatment. Gross income was determined from a base carcass price plus premiums or discounts.

A total of 64 income over feed cost alternatives were created from combinations of the eight dietary treatments; four scenarios for corn, soybean meal (SBM), fat, and base hog prices; and two different packing plant grids to determine premiums and discounts (8 × 4 × 2).

Fixed premiums and weight discounts were used in grid 1 and, therefore, the premiums and weight discounts were independent of base price. An index for premiums and discounts, which represented a percentage of the base hog price, was used for calculating income with grid 2.

The four scenarios for ingredient and hog prices are presented in Table 2. 1) Corn and SBM prices from Southwestern MN for December of 1998 with choice white grease (CWG) at $.12/lb and hog carcass at $41.1/CWT. 2) Same as 1, but with CWG at $.20/lb. 3) Same as 1, but with CWG at $.10/lb. 4) Average prices from 1997 for corn, SBM, and hogs with CWG at $.12/lb.

Income over feed cost per pen (six pens per treatment) was used to analyze the 64 alternatives, using first and second-degree stochastic dominance. This is a technical procedure used to evaluate the profitability and riskiness of alternative production strategies. A dominant strategy is either more profitable, less risky, or both. Therefore, a less profitable strategy may be dominant if it is less risky. Riskiness can be defined as having a higher probability of low outcomes and/or a higher level of variability.

Results and Discussion

The 64 combination alternatives for income over feed cost are presented in Table 3. The stochastic dominance analysis results (Table 4) are interpreted as follows: Strategies denoted with the number 1 or 2 are preferred alternatives, with 2 being dominant over 1. Strategies denoted with the number 0 are alternatives that will not be chosen by producers because they are more risky or are inferior in terms of income over feed cost.

In general, the fourth (highest) lysine: calorie ratio with added fat was the preferred strategy. However, when the price of fat was high in relation to corn and SBM prices, the fourth lysine:calorie ratio without added fat was preferred under both grids. The first and second lysine calorie ratios were not preferred strategies, regardless of added fat level and scenario.

Adding fat to the diets improves growth performance (p. 88); therefore, it is not surprising that the price of fat altered the income over feed cost.

For scenarios 1 and 3, adding fat to the diets was a dominant strategy for the fourth lysine:calorie ratio under the two grids. The third lysine:calorie ratio was also dominant when fat was added to the diets but only under grid 2.

For scenario 2 (high price for fat) and using grid 1, the fourth lysine:calorie ratio without added fat was favored. Using grid 2, the fourth lysine:calorie ratio was preferred regardless of whether fat was added to the diet or not.

For scenario 4, the third and fourth lysine:calorie ratios with added fat were dominant regardless of the grid used. The rest of the strategies were not preferred.

It is of interest that the third lysine:calorie ratio regimen with added fat was also preferred in scenarios 1 and 3, but

only when evaluated under grid 2. The reason for this might be the fact that grid 2 places more value on carcass weight and grid 1 on percent lean premium. Pigs fed the fourth lysine:calorie ratio with added fat had a decreased backfat depth and an increased fat-free lean index, which might explain why carcasses of similar weight were graded differently between grids. These results suggest that feeding strategies should be different when selling pigs under different grids.

One of the reasons why adding fat to the diets improved the income over feed cost is the improvement in ADG, and consequently, the improvement in carcass weight. We considered that all pigs were marketed on the same day. This increases weight discounts and decreases gross income for the pigs that grew slower (fed diets without added fat). Thus, if pig flow permits, an economic analysis should be performed to evaluate the income over feed cost using a partial marketing strategy and allowing for slower growing pigs to be sold at a similar weight as pigs fed dietary fat. The extra gross income received by allowing pigs to grow to heavier weights would have to justify the extra facility and feed costs.

Table 1. Dietary Treatments

	Lysine:Calorie Ratio (g lysine/Mcal ME)							
	0% Fat				6% Fat			
Item	A	B	C	D	E	F	G	H
Phase 1 (60-100 lb)	2.96	3.26	3.56	3.86	2.96	3.26	3.56	3.86
Phase 2 (100-165 lb)	2.25	2.50	2.75	3.00	2.25	2.50	2.75	3.00
Phase 3 (165-220 lb)	1.64	1.84	2.04	2.24	1.64	1.84	2.04	2.24
Phase 4 (220-260 lb)	1.12	1.32	1.52	1.72	1.12	1.32	1.52	1.72

Table 2. Ingredient and Hog Price Scenarios

	Scenario							
	1 SW Minnesota		2 High Fat Price		3 Low Fat Price		4 1997 Prices	
Item	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2
Corn $/lb	.034	.034	.034	.034	.034	.034	.047	.047
SBM $/Ton	130	130	130	130	130	130	176	176
CWG $/lb	.12	.12	.20	.20	.10	.10	.15	.15
Hog Carcass $/CWT	41.1	41.1	41.1	41.1	41.1	41.1	69.3	69.3

Table 3. Income over Feed Cost for the Dietary Treatments under Different Scenarios[a]

	Scenario							
	1 SW Minnesota		2 High Fat Price		3 Low Fat Price		4 1997 Prices	
Treatments	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2
A	$52.93	$46.35	$52.93	$46.35	$52.93	$46.35	$96.51	$86.81
B	$57.08	$52.48	$57.08	$52.48	$57.08	$52.48	$102.04	$97.20
C	$59.89	$56.22	$59.89	$56.22	$59.89	$56.22	$106.51	$103.76
D	$61.61	$58.91	$61.61	$58.91	$61.61	$58.91	$109.38	$108.54
E	$57.35	$47.11	$50.12	$44.41	$53.49	$47.79	$97.02	$88.94
F	$57.81	$54.82	$55.10	$52.10	$58.49	$55.50	$104.75	$102.19
G	$60.94	$60.53	$58.16	$57.75	$61.63	$61.22	$111.59	$112.26
H	$62.88	$62.37	$60.23	$59.73	$63.64	$63.03	$113.11	$115.08

[a]Growth performance and carcass characteristics data from 1,200 growing-finishing gilts (PIC C22 × 337) were used to calculate the income over feed cost for each treatment under each scenario.

Table 4. First and Second Stochastic Dominance Results on Income over Feed Cost[a]

	Scenario[b]							
	1 SW Minnesota		2 High Fat Price		3 Low Fat Price		4 1997 Prices	
Treatments	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2
A	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0
D	0	0	2	2	0	0	0	0
E	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0
G	0	2	0	0	0	2	0	2
H	2	2	0	2	2	2	2	2

[a]For each scenario, the preferred treatments are indicated with the numbers 1 and 2, where 2 is preferred over 1, and 0 is a not preferred alternative.
[b]The data from 1,200 growing-finishing gilts (PIC C22 × 337) were used for the analysis of each scenario.

EFFECTS OF MODIFIED TALL OIL AND CREATINE MONOHYDRATE ON GROWTH PERFORMANCE, CARCASS CHARACTERISTICS, AND MEAT QUALITY OF GROWING-FINISHING BARROWS[1]

P. R. O'Quinn, B. S. Andrews, R. D. Goodband, J. A. Unruh, J. L. Nelssen, J. C. Woodworth, and M. D. Tokach[2]

Summary

A trial was conducted to evaluate the effects of modified tall oil (MTO; .50% of the diet) and creatine monohydrate (CMH; 25 g/pig/day for 10 days prior to slaughter) on performance, carcass characteristics, and meat quality of finishing barrows. Feeding MTO improved ADG and F/G during the growing phase and improved F/G over the entire trial and during the 10 day CMH loading period. Feeding MTO reduced backfat, but neither CMH nor MTO affected other carcass characteristics or meat quality measures at 24 h postmortem. These data suggest that MTO improves performance and reduces backfat with little effect on meat quality, whereas CMH does not appear to be beneficial to growing-finishing swine.

(Key Words: Modified Tall Oil, Creatine Monohydrate, Barrows, Meat Quality.)

Introduction

Prior work at Kansas State University has shown that MTO is an effective feed additive for improving growth performance and carcass leanness of growing-finishing pigs. Modified tall oil also has been shown to increase belly firmness and may potentially play a role in improving pork quality. Creatine is a nutritional supplement routinely taken by athletes to increase muscle mass. This increase in muscle mass is initiated by a hydration of the cell that leads to the stimulation of proteolysis. This stimulation should increase percentage lean and potentially increase the tenderness of pork. Modified tall oil increases carcass lean content primarily through reductions in backfat, whereas CMH supplementation should increase percentage lean through actual increases in protein content. Therefore, we postulated that feeding MTO and CMH together would increase weight gains, improve carcass leanness, and improve measures of meat quality.

Procedures

Pigs used in this experiment were terminal offspring of PIC L326 or 327 boars × C22 sows (PIC, Franklin, KY). Experimental procedures were approved by the Kansas State University Institutional Animal Care and Use Committee (Protocol No. 1639).

The 80 crossbred barrows (initially 100.1 lb BW) were blocked on the basis of initial weight and ancestry in a randomized complete block design and allotted randomly to one of four dietary treatments arranged as a 2 × 2 factorial with 10 replicate pens per treatment. Because two of the four dietary treatments were not implemented until 10 days preslaughter, there were 20 replicate pens per dietary treatment until then.

Diets were fed in two phases (100.1 to 173.9 and 173.9 to 259.0 lb BW; Table 1).

[1]Appreciation is expressed to Hercules, Inc., Wilmington, DE, for providing the modified tall oil used in this experiment; to Lonza, Inc., Fair Lawn, NJ, for providing the creatine monohydrate and for partial financial support of this experiment; and to Colin Bradley of the London Health Sciences Centre, London, Ontario, Canada, for conducting the serum creatinine analysis.

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

Preselected pens of pigs were changed to CMH-supplemented diets at 10 days pre-slaughter (237.0 lb BW). Modified tall oil was substituted on an equal weight basis for soybean oil, and CMH (99% creatine) was substituted on an equal weight basis (.75% of the total diet) for ground corn to achieve the additional dietary treatments. The targeted level of creatine intake chosen for this experiment (25 g/d for 10 days) was based on prior research with swine at the University of Missouri.

Pigs were housed in an environmentally controlled finishing barn with two pigs in each 4 ft × 4 ft totally slatted-floored pen. They were allowed ad libitum access to feed and water through one single-hole self-feeder and a nipple waterer, respectively. Pigs were weighed every 14 d in order to determine ADG, ADFI, and F/G and also at the beginning and end of the CMH loading period. Serum samples also were obtained from one pig per pen at the beginning and end of the CMH loading period for determination of initial and final creatinine levels. Creatinine is the sole metabolite of creatine. Feed was not withheld from pigs prior to blood sampling, which was conducted only on pigs not being slaughtered. This was done so that the potential stress of blood sampling would not interfere with or influence measures of meat quality. Serum creatinine samples were stored frozen until analyzed.

One pig (closest to the average weight of all pigs) per pen was slaughtered after 10 days of receiving CMH (average slaughter weight of 259.0 lb). Standard carcass measurements; visual analyses of the longissimus for coloring, marbling, and firmness; drip loss; water-holding capacity; ultimate pH; and color spectrophotometry (L*, a*, and b*) were obtained for each pig at 24 h postmortem (drip loss = 48 h postmortem). Boneless loins were removed from the right sides of all carcasses, vacuum packaged, and stored for 14 days at 39°F. Then purge loss, drip loss, water-holding capacity, pH, visual analysis, and color spectrophotometry were determined again after loins were removed from vacuum bags and allowed 15 min for standardization. A 1-in-thick chop also was also taken from each loin and used for the determination of Warner Bratzler shear force values using a v-blade attachment for an Instron Model 5401 compression machine. The speed of the v-blade during all measurements was 5 mm/min. Cores (.5 in. diameter) used for the tenderness evaluations were taken parallel to the muscle fiber orientation. Prior to testing, chops were cooked to an internal core temperature of 158°F. Raw and cooked chop weights were recorded and used for the determination of percentage thawing and cooking losses.

Data were analyzed as a randomized complete block. Pen was the experimental unit for the growth performance data and individual pig (one pig/pen) for the carcass characteristics and serum creatinine measurements. The GLM procedure of SAS was used for the single degree of freedom contrast between the two dietary treatments during the growing-finishing period of the growth trial. All subsequent data including the last 10 days of the finishing period were analyzed as a 2 × 2 factorial arrangement with main effects of MTO (0 or .50% of the diet) or CMH (0 or 25 g/d for 10 days pre-slaughter). The statistical model included main effects and interactions of the main effects. Hot carcass weight was used as a covariate in the statistical model for carcass analysis.

Results and Discussion

Growth Data. Feeding MTO improved ($P<.05$) ADG and F/G during the growing period, but had no effect ($P>.15$) on growth performance during the finishing period (Table 2). The early improvements in feed efficiency also carried through for improved ($P = .10$) F/G from MTO over the total trial. The 10-day addition of CMH numerically ($P = .11$) improved ADG and F/G, presumably from increased water retention (Table 3). Modified tall oil improved ($P = .02$) F/G and increased ($P = .08$) ADG during the CMH loading period. An interaction ($P = .09$) of MTO and CMH was observed for ADFI; feeding CMH increased ADFI when diets contained MTO but reduced feed intake when diets did not contain MTO.

Carcass Characteristics. Feeding 25 g of CMH per pig for 10 days prior to slaughter had no effect (P>.20) on carcass characteristics or serum creatinine levels (Table 4). Feeding MTO reduced (P<.05) tenth and last rib backfat, which also resulted in reduced (P = .05) average backfat. Modified tall oil did not affect (P>.10) other carcass characteristics or serum creatinine levels.

Meat Quality. Dietary treatment did not affect (P>.10) any measured parameter of meat quality at 24 h postmortem (Table 5).

Feeding CMH did not affect (P>.20) any measured parameter of meat quality at 14 d postmortem (Table 6), but feeding MTO increased (P = .02) L* values and tended to increase (P<.10) thawing and cooking losses of chops. The changes in L* values (paleness) were small and probably not detectable by the eye as evidenced by the lack of visual color response. Modified tall oil did not affect (P>.15) other measures of meat quality at 14 d postmortem including pH, other color determinations, drip loss, water-holding capacity, or shear force.

Consistent with prior reports, MTO appears to be a potential growth promoter and improves carcass leanness through reductions in backfat. Modified tall oil also appears to have minimal impact on meat quality by itself, although increases in intramuscular marbling from MTO alone have been reported. When fed in conjunction with elevated levels of vitamin E, MTO helps to decrease oxidation and increase shelf-life and color stability. Under the conditions of this study, CMH supplementation was not beneficial in the diets of growing-finishing pigs. However, different approaches to CMH supplementation could be employed involving different lengths of supplementation, different levels of supplementation, or a combination thereof. More work is necessary to determine if CMH can be used successfully in swine diets, but supplementation of MTO should improve growth performance and reduce backfat.

Table 1. Composition of Basal Diets (As-Fed Basis)

Ingredient, %	Growing[a]	Finishing[b]	10-d Preslaughter[c]
Corn	69.24	78.58	77.83
Soybean meal (46.5% CP)	27.47	18.39	18.39
Limestone	1.06	.89	.89
Monocalcium phosphate	.85	.76	.76
Soybean oil[d]	.50	.50	.50
Salt	.35	.35	.35
Vitamin premix	.25	.25	.25
Trace mineral premix	.15	.15	.15
Antibiotic[e]	.13	.13	.13
Creatine monohydrate[f]	----	----	.75
Total	100.00	100.00	100.00

[a]Growing diets were fed from 100.1 to 173.9 lb BW and were formulated to contain 1.00% lysine, .65% Ca, and .55% total P.
[b]Finishing diets were fed from 173.9 to 259.0 lb BW and were formulated to contain .75% lysine, .55% Ca, and .50% total P.
[c]Diets were fed for 10 days prior to slaughter (237.0 to 259.0 lb BW) and were formulated to contain .75% lysine, .55% Ca, and .50% total P.
[d]Soybean oil was substituted on an equal weight basis for MTO to give the experimental treatments.
[e]Provided 100 g/ton tylosin.
[f]Creatine monohydrate was substituted on an equal weight basis (.75 % of total diet) for corn during the last 10 days of the finishing period to achieve the additional dietary treatments.

Table 2. Growth Performance of Barrows Fed MTO (100.1 to 237.0 lb BW)[a]

	MTO, %			Contrast Probability
Item	0	.50	CV	(*P* =)
100.1 to 173.9 lb BW				
ADG, lb	2.33	2.44	6.97	.04
ADFI, lb	6.21	6.21	6.56	.97
F/G	2.67	2.55	6.63	.03
173.9 to 237.0 lb BW				
ADG, lb	2.37	2.33	12.28	.66
ADFI, lb	7.57	7.31	8.40	.20
F/G	3.23	3.15	9.14	.43
100.1 to 237.0 lb BW				
ADG, lb	2.35	2.38	6.76	.52
ADFI, lb	6.81	6.68	6.04	.35
F/G	2.91	2.81	6.16	.10

[a]Values are means for two pigs per pen and 20 replicate pens per treatment.

Table 3. Growth Performance of Barrows Fed MTO, Creatine, or Both (237.0 to 259.0 lb BW)[a]

	0 MTO/CMH		.50% MTO/CMH			Probability values (*P* =)		
Item	0	25 g/d	0	25 g/d	CV	MTO × CMH	MT	CMH
ADG, lb	2.25	2.40	2.42	2.83	21.34	.46	.08	.11
ADFI, lb	8.19	7.96	7.81	8.36	8.70	.09	.95	.48
F/G	3.89	3.47	3.29	2.98	20.17	.80	.02	.11

[a]Values are means of two pigs per pen and 10 replicate pens per treatment.

Table 4. Carcass Characteristics of Barrows Fed MTO, Creatine, or Both[a,b]

	0 MTO/CMH		.50% MTO/CMH			Probability Values (*P* =)		
Item	0	25 g/d	0	25g/d	CV	MTO × CMH	MTO	CMH
Shrink loss, %	.65	.88	1.02	.83	73.99	.30	.39	.87
Backfat, in								
First rib	1.64	1.59	1.49	1.55	12.38	.39	.11	.83
Tenth rib	.94	.99	.80	.85	18.26	.96	.01	.30
Last rib	.91	.98	.82	.87	15.53	.87	.02	.24
Last lumbar	.87	.91	.78	.86	18.86	.73	.19	.28
Average[c]	1.14	1.16	1.03	1.09	13.16	.65	.05	.50
LMA, in^2	6.21	6.51	6.51	6.38	11.17	.33	.78	.76
Lean %[d]	51.14	51.24	53.19	52.22	5.56	.56	.18	.49
Dressing %	73.88	73.72	73.58	73.74	1.47	.66	.21	.36
Carcass length, in	32.35	32.86	32.75	32.53	2.29	.14	.84	.94
Serum creatinine, mg/L								
Initial	1.37	1.40	1.50	1.40	13.01	.29	.30	.52
Final	1.55	1.58	1.66	1.58	13.71	.45	.50	.70

[a]Values represent one pig per pen and 10 replicate pens per treatment.
[b]Hot carcass weight was used as a covariate in the statistical analysis.
[c]Average backfat is the average of the first and last rib and last lumbar fat depths.
[d]Lean percentage was derived from NPPC (1991) equations with 5% fat in the carcass.

Table 5. Longissimus Quality Measures of Barrows Fed MTO, Creatine, or Both (24 h Postmortem)[a]

	0 MTO/CMH		.50% MTO/CMH			Probability Values (*P* =)		
Item	0	25 g/d	0	25 g/d	CV	MTO×CMH	MTO	CMH
pH	5.41	5.39	5.39	5.40	1.95	.59	.70	.83
Visual color[b]	2.60	2.40	2.45	2.40	22.16	.67	.70	.51
Firmness[b]	2.95	2.80	2.60	2.80	23.57	.40	.64	.64
Marbling[b]	2.60	2.30	2.35	2.40	20.78	.27	.79	.58
L*[c]	56.58	57.19	57.80	56.80	4.84	.36	.64	.82
a*[c]	9.97	9.35	9.98	9.26	19.76	.94	.95	.27
b*[c]	19.28	18.16	18.74	17.48	17.20	.95	.55	.24
Hue angle[c]	62.61	62.92	62.08	62.29	2.65	.93	.27	.62
Saturation index[c]	21.71	20.43	21.24	20.49	15.06	.80	.84	.32
a*/b*[c]	.52	.51	.53	.53	6.90	.90	.28	.57
%R630/%R580[c]	2.87	2.72	2.78	2.69	13.18	.78	.58	.30
%R610/%R580[c]	2.47	2.33	2.39	2.32	13.07	.75	.66	.31
Drip loss, %	5.01	4.20	5.48	5.74	50.30	.51	.13	.98
Water-holding capacity, %[d]	3.36	3.49	3.92	3.60	19.74	.32	.15	.67

[a]Values represent one pig per pen and 10 replicate pens per treatment.

[b]Scoring system of 1 to 5: 2 = grayish pink, traces to slight, or soft and watery; 3 = reddish pink, small to modest, or slightly firm and moist; and 4 = purplish red, moderate to slightly abundant, or firm and moderately dry for color, firmness, and marbling, respectively.

[c]Means were derived from two sample readings per loin. Measures of dark to light (L*), redness (a*), yellowness (b*), red to orange (hue angle),vividness or intensity (saturation index), or reflectance values (%R630/%R580 and %R610/%R580).

[d]Determined by dividing the area of the meat by the area of the fluid after compression with a Carver press.

Table 6. Longissimus Quality Measures of Barrows Fed MTO, Creatine, or Both (14 d Postmortem)[a]

	0 MTO/CMH		.50% MTO/CMH			Probability Values (P =)		
Item	0	25 g/d	0	25 g/d	CV	MTO × CMH	MTO	CMH
pH	5.43	5.43	5.42	5.42	1.84	.97	.65	.75
Visual color[b]	2.40	2.45	2.45	2.40	14.57	.64	.64	.63
Firmness[b]	2.90	2.90	2.95	2.90	11.40	.81	.99	.66
Marbling[b]	2.50	2.40	2.20	2.35	23.13	.48	.19	.81
L*[c]	55.01	54.99	56.66	56.75	4.08	.94	.02	.96
a*[c]	19.41	21.12	20.87	20.79	11.21	.23	.44	.27
b*[c]	6.90	7.65	7.65	7.72	14.09	.31	.23	.23
Hue angle[c]	21.19	19.93	20.13	20.35	10.40	.28	.64	.45
Saturation index[c]	21.13	22.46	22.22	22.17	8.28	.24	.49	.28
a*/b*[c]	2.67	2.77	2.73	2.70	6.16	.24	.96	.60
%R630/%R580[c]	2.65	2.79	2.70	2.67	8.78	.25	.64	.48
%R610/%R580[c]	2.28	2.38	2.33	2.89	7.96	.22	.74	.59
Drip loss, %	1.59	1.65	1.19	1.49	82.03	.77	.48	.66
Water-holding capacity, %[d]	3.77	3.57	3.98	3.65	23.21	.81	.59	.34
Loin purge loss, %	2.93	2.60	3.12	3.50	43.37	.37	.16	.88
Chop thawing loss, %	7.05	6.88	7.62	7.53	15.78	.91	.10	.73
Chop cooking loss, %	26.53	25.81	29.17	29.53	24.62	.76	.09	.92
Chop shear force, kg	2.55	2.60	2.71	2.87	17.83	.73	.17	.51

[a]Values represent one pig per pen and 10 replicate pens per treatment.

[b]Scoring system of 1 to 5: 2 = grayish pink, traces to slight, or soft and watery; 3 = reddish pink, small to modest, or slightly firm and moist; and 4 = purplish red, moderate to slightly abundant, or firm and moderately dry for color, firmness, and marbling, respectively.

[c]Means were derived from two sample readings per loin. Measures of dark to light (L*), redness (a*), yellowness (b*), red to orange (hue angle), vividness or intensity (saturation index), or reflectance values (%R630/%R580 and %R610/%R580).

[d]Determined by dividing the area of the meat by the area of the fluid after compression with a Carver press.

EFFECTS OF MODIFIED TALL OIL, CHROMIUM NICOTINATE, AND L-CARNITINE ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF GROWING-FINISHING GILTS[1]

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Summary

A trial was conducted to investigate the interactive effects of modified tall oil (MTO), chromium nicotinate (CrNic), and L-carnitine on growth performance and carcass characteristics of finishing gilts. For the overall trial, MTO increased ADG and ADFI, and CrNic improved F/G. A CrNic × MTO interaction occurred for belly firmness; feeding CrNic in diets without MTO improved firmness, but feeding it in diets with MTO decreased firmness. Feeding L-carnitine did not have any beneficial effects on either growth performance or carcass characteristics. The results of this trial indicate that either CrNic or MTO will improve growth performance with minimal effects on carcass characteristics.

(Key Words: Modified Tall Oil, Chromium Nicotinate, L-Carnitine, Gilts.)

Introduction

Modified tall oil is an oily coproduct from the kraft (sulfate) paper process and contains high levels (~70%) of conjugated linoleic acid. Prior work at Kansas State University has shown MTO to be an effective carcass modifier in finishing swine in terms of reducing backfat and increasing carcass lean content. When fed in conjunction with high levels of vitamin E, MTO improves and maintains fresh pork color over time, delays lipid oxidation, and increases shelf life of the longissimus muscle. Earlier work has also shown that both CrNic and L-carnitine improve fresh pork color and may work synergistically. However, this earlier study did not evaluate the effects of CrNic and L-carnitine on the further stability of pork color. Modified tall oil, CrNic, and L-carnitine are all known to potentially improve growth performance and carcass characteristics in growing pigs, and all may play a role in the maintenance of pork color. Therefore, this study was undertaken to determine if feeding them in combinations would additively improve growth performance and carcass characteristics of finishing weight gilts.

Procedures

Procedures used in this experiment were approved by the Kansas State University Institutional Animal Care and Use Committee (Protocol No. 1525). A total of 80 crossbred gilts (initially 100 lb; PIC L326 or 327 × C22, Franklin, KY) was used. Pigs were blocked on the basis of initial weight and ancestry and randomly allotted to one of eight dietary treatments with five replicate pens per treatment.

Diets were fed in meal form in two phases (100 to 160 and 160 to 235 lb; Table 1). Modified tall oil was substituted for soybean oil on an equal weight basis, and

[1]Appreciation is expressed to Hercules, Inc., Wilmington, DE, for providing the modified tall oil used in this experiment and to Lonza, Inc., Fair Lawn, NJ, for providing the chromium nicotinate and L-carnitine and for partial financial support of this experiment.

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

[3]Lonza, Inc., Fair Lawn, NJ.

CrNic and L-carnitine were mixed with the complete diet to achieve the experimental diets, which were arranged as a 2 × 2 × 2 factorial design with two levels of MTO (0 or 0.50%), two levels of CrNic (0 or 50 ppb), and two levels of L-carnitine (0 or 50 ppm). This is the first study to have supplemental oil in diets also containing MTO, and thus, gives insight into the ability of MTO to elicit biological responses when supplemental fat is also present.

Pigs were housed in an environmentally controlled finishing barn with two pigs in each 4 ft × 4 ft totally slatted-floored pen. They were allowed ad libitum access to feed and water through one single-hole self-feeder and a nipple waterer. Pigs were weighed every 14 d in order to determine ADG, ADFI, and F/G.

Pigs were slaughtered when their average weight reached 235 lb. Standard carcass measurements; visual analyses of the longissimus for coloring, marbling, and firmness; longissimus drip loss, and color spectrophotometry of the adipose tissue and longissimus muscle were determined for each pig at 28 h postmortem (drip loss = 48 h postmortem). During fabrication of the carcasses (26 h postmortem), bellies from the right sides of all pigs were removed and evaluated for firmness.

Data were analyzed as a randomized complete block. Pen was the experimental unit for all calculations. The GLM procedures of SAS were used for all analyses. The data were analyzed as a 2 × 2 × 2 factorial with main effects of MTO (0 or 0.50% of the diet), CrNic (0 or 50 ppb), and L-carnitine (0 or 50 ppm). The statistical model included main effects and all possible interactions of the main effects. Hot carcass weight was used as a covariate in the statistical model for carcass analyses, and belly weights and lengths were used as covariates in the statistical model for analyses of belly firmness.

Results and Discussion

Growth Data. From 160 to 235 lb, pigs fed CrNic grew faster (P = .09) and were more efficient (P = .08) compared to pigs fed other dietary treatments (Table 2). Pigs fed MTO consumed more feed (P = .06) during this same time period; however, feeding L-carnitine and CrNic together reduced (P = .07) ADFI during this final phase of growth. These results led to overall increases in ADG (P = .03) and ADFI (P = .10) for pigs fed MTO and an improvement in feed efficiency (P = .02) for pigs fed CrNic. Feeding L-carnitine did not elicit any growth performance responses in this group of growing-finishing gilts.

Carcass Characteristics. Dietary treatment combinations did not affect (P>.10) carcass characteristics such as backfat thickness, longissimus muscle area, percentage lean, drip loss, shrink loss, or firmness and marbling of the longissimus (Table 3). Feeding L-carnitine decreased visual color appraisal of the longissimus, but improved it when fed in conjunction with MTO (P = .10). The combination of MTO and CrNic resulted in an interaction (P = .07) for adipose a* values; CrNic reduced a* values in diets not containing MTO, but increased them in diets containing MTO. The response in adipose a* values also affected (P = .04) hue angle and a*/b* values. Thus, CrNic reduced the redness (a* values) of fat by itself, but increased it in diets containing MTO. These a* values are indicative of a slight browning or discoloration, though it probably was not detectable by visual appraisal. However, the whiteness of the fat (L* values) was not affected (P>.10) by dietary treatment. Feeding CrNic alone improved belly firmness, but feeding it with MTO decreased firmness (P<.05). Although both MTO and CrNic alone may improve belly firmness, the responses to MTO appeared to be substantially larger.

The relatively small values for belly firmness may be related to the leanness of the gilts, the light market weights, the effects of added fat, or a combination thereof. Even though the magnitude of the response was small, MTO still evoked a belly-firming effect when fed in conjunction with additional dietary fat. Because of the relatively light slaughter weights, the gilts still should

have had high protein deposition versus fat deposition; thus, this trial also gives insight into the ability of MTO to elicit biological responses when fed to lightweight, high-lean gilts. This is of importance, because most of the increases in percentage lean from feeding MTO have come from reductions in backfat and not from increases in muscling.

Aside from potential improvements in belly firmness from CrNic and MTO, feeding CrNic, L-carnitine, or MTO did not elicit any beneficial carcass responses in the current experiment. Feeding either MTO (ADG and ADFI) or CrNic (F/G) alone may improve growth performance, but L-carnitine was not beneficial in the diets of growing-finishing pigs in this trial.

Table 1. Composition of Basal Diets (As-Fed Basis)

Ingredient, %	Growing[a]	Finishing[b]
Corn	66.50	76.93
Soybean meal (46.5% CP)	27.70	18.53
Soybean oil[c]	3.00	2.00
Limestone	1.04	.88
Monocalcium phosphate	.88	.78
Salt	.35	.35
Vitamin premix	.25	.25
Trace mineral premix	.15	.15
Antibiotic[d]	.13	.13
Total	100.00	100.00

[a]Diets were fed from 100 to 160 lb and were formulated to contain 1.00% lysine, .65% Ca, and .55% total P.

[b]Diets were fed from 160 to 235 lb and were formulated to contain .75% lysine, .55% Ca, and .50% total P.

[c]Modified tall oil was substituted on an equal weight basis for soybean oil; CrNic and L-carnitine were incorporated into the complete diet to give the additional dietary treatments.

[d]Provided 100 g/ton tylosin.

Table 2. Growth Performance of Pigs Fed Modified Tall Oil, Chromium Nicotinate, or L-Carnitine[a]

	MTO, %												
	0	0	0	0	.50	.50	.50	.50					
	CrNic, ppb												
	0	50	0	50	0	50	0	50					
	L-Carnitine, ppm									Probability Values (P =)			
Item	0	0	50	50	0	0	50	50	CV	CrNic	L-Carn.	MTO	Interactions[b]
100 to 160 lb													
ADG, lb	2.23	2.05	2.19	2.21	2.17	2.29	2.26	2.29	7.48	.95	.33	.13	.15
ADFI, lb	5.22	4.85	5.13	5.21	5.19	5.07	5.20	5.15	8.51	.40	.52	.72	.36
F/G	2.34	2.36	2.34	2.35	2.39	2.21	2.31	2.26	6.60	.31	.80	.25	.19
160 to 235 lb													
ADG, lb	1.92	2.03	1.95	2.01	2.02	2.17	1.99	2.11	9.97	.09	.77	.15	.68
ADFI, lb	5.43	5.49	5.55	4.92	5.54	6.03	5.84	5.52	11.22	----	----	.06	[c]
F/G	2.86	2.74	2.85	2.49	2.75	2.78	2.97	2.62	12.74	.08	.68	.69	.17
100 to 235 lb													
ADG, lb	2.06	2.04	2.06	2.11	2.09	2.23	2.13	2.19	6.27	.19	.70	.03	.28
ADFI, lb	5.48	5.38	5.52	5.18	5.54	5.67	5.71	5.42	6.64	.20	.60	.10	.17
F/G	2.67	2.65	2.67	2.47	2.65	2.54	2.70	2.47	7.02	.02	.41	.64	.20

[a]Values are means of two pigs per pen and five replicate pens per dietary treatment.

[b]Refers to the P-value of the most significant of all possible interactions (2- and 3-way).

[c]Chromium nicotinate × L-carnitine, P = .07; other interactions, nonsignificant, P>.35.

Table 3. Carcass Characteristics of Pigs Fed Modified Tall Oil, Chromium Nicotinate, or L-Carnitine[a,b]

	MTO, %												
	0	0	0	0	.50	.50	.50	.50					
	CrNic, ppb												
	0	50	0	50	0	50	0	50					
	L-Carnitine, ppm									Probability Values (P =)			
Item	0	0	50	50	0	0	50	50	CV	CrNic	L-Carn.	MTO	Int.[c]
Shrink loss, %	1.15	1.16	1.20	1.04	1.05	1.24	1.25	1.18	36.80	.99	.83	.71	.46
Dressing %	74.15	74.49	74.30	74.95	74.64	73.81	74.81	74.63	1.41	----	.12	----	[d]
Backfat, in.													
First rib	1.43	1.40	1.43	1.49	1.43	1.44	1.41	1.43	8.18	.96	.71	.47	.73
Last rib	.76	.70	.78	.84	.76	.78	.79	.79	8.65	.87	.25	.64	.41
Last lumbar	.68	.63	.67	.69	.68	.72	.68	.67	12.56	.76	.41	.58	.65
10th rib	.65	.59	.64	.72	.69	.66	.63	.65	15.00	.86	.83	.39	.30
Average[e]	.96	.91	.96	1.00	.96	.98	.96	.96	7.62	.84	.87	.99	.64
LMA, in^2	5.70	5.86	5.85	5.96	6.01	6.11	6.08	6.30	7.22	.44	.39	.15	.70
Lean, %[f]	53.97	54.96	54.35	53.52	54.07	54.41	54.76	54.98	3.06	.79	.50	.79	.45
Longissimus													
Visual color[g]	2.70	2.70	2.40	2.00	2.10	2.10	2.30	2.15	16.88	.49	----	----	[h]
Firmness[g]	2.35	2.35	2.50	2.10	2.25	2.30	2.50	2.30	18.10	.60	.43	.40	.31
Marbling[g]	2.15	2.00	2.20	1.90	1.85	1.95	2.25	1.95	15.60	.16	.29	.80	.21
L*[i]	58.72	58.78	58.71	60.99	62.25	60.05	58.27	59.52	7.24	.80	.68	.60	.23
a*[i]	8.47	8.70	8.54	8.43	8.26	8.77	8.76	8.78	15.95	.71	.86	.81	.64
b*[i]	15.70	16.48	16.40	17.03	16.76	16.91	16.11	16.96	9.26	.22	.74	.56	.35
Hue angle[i]	61.96	62.29	62.61	63.72	63.97	62.75	61.56	62.59	4.01	.70	.88	.93	.15
Saturation index[i]	17.86	18.64	18.50	19.02	18.70	19.07	18.35	19.11	10.20	.32	.77	.62	.59
a*/b*[i]	.53	.53	.52	.50	.49	.52	.54	.52	10.54	.68	.89	.92	.15

Table 3. Continued

%R630/%R580[i]	2.45	2.44	2.45	2.42	2.37	2.47	2.50	2.51	14.09	.87	.72	.84	.69
Drip loss, %	4.23	5.31	4.22	5.61	5.85	5.52	5.47	6.10	25.18	.35	.27	.53	.26
Adipose													
L*[i]	83.76	83.89	84.09	83.82	84.33	84.41	85.15	84.19	1.85	.61	.65	.20	.46
a*[i]	1.52	.77	1.59	1.33	1.15	1.80	1.13	1.57	60.52	----	.73	----	[j]
b*[i]	10.31	9.24	9.32	10.17	9.91	10.17	10.19	9.79	14.82	.85	.93	.58	.17
Hue angle[i]	81.73	85.53	81.38	83.17	83.95	80.51	83.91	81.80	4.46	----	.78	----	[k]
Saturation index[i]	10.42	9.28	9.40	10.27	10.00	10.26	10.28	9.88	15.43	.83	.94	.59	.18
a*/b*[i]	.15	.08	.15	.12	.11	.17	.11	.14	53.47	----	.78	----	[k]
%R630/%R580[i]	1.36	1.29	1.31	1.34	1.32	1.32	1.32	1.30	4.47	.52	.67	.71	.16
Belly firmness, in.													
Initial	4.43	4.75	5.05	5.60	7.35	6.70	8.18	5.20	23.74	----	.81	----	[l]
1 min	4.13	4.33	4.65	5.08	6.45	5.95	7.33	4.75	21.71	----	.82	----	[l]
5 min	3.75	3.98	4.33	4.88	5.85	5.43	6.50	4.48	19.02	----	.91	----	[l]

[a]Values are means of two pigs per pen and five replicate pens per dietary treatment.

[b]Hot carcass weight was used as a covariate in the statistical model for carcass characteristics, and belly weights and lengths were used as covariates in the statistical model for belly firmness.

[c]Refers to the probability value of the most significant of all possible interactions (2 and 3-way).

[d]Modified tall oil × CrNic, P = .07; other interactions, nonsignificant, P>.10.

[e]Average backfat is the average of the first and last rib and last lumbar backfats.

[f]Lean percentage was derived from NPPC (1991) equations with 5% fat in the carcass.

[g]Scale of 1 to 5: 2 = grayish pink, soft and watery, or traces to slight; 3 = reddish pink, slightly firm and moist, or small to modest; and 4 = purplish red, firm and moderately dry, or moderate to slightly abundant for color, firmness, and marbling, respectively.

[h]Modified tall oil × L-carnitine, P = .10; other interactions, nonsignificant, P > .10.

[i]Means were derived from two sample readings per loin. Measures of dark to light (L*), redness (a*), yellowness (b*), red to orange (hue angle), vividness or intensity (saturation index), and reflectance values (%R630/%R580).

[j]Modified tall oil × CrNic, P = .07; other interactions, nonsignificant, P>.15.

[k]Modified tall oil × CrNic, P = .04; other interactions, nonsignificant, P>.15.

[l]Modified tall oil × CrNic, P<.05; other interactions, nonsignificant, P>.10.

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EFFECTS OF MODIFIED TALL OIL AND VITAMIN E ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF GROWING-FINISHING BARROWS[1]

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Summary

A trial was conducted to investigate the interactive effects of modified tall oil (MTO) and vitamin E on growth performance and carcass characteristics of growing-finishing barrows. Feeding MTO resulted in increased ADG and improved F/G during the growing phase; otherwise dietary treatment did not affect growth performance during the rest of the trial or overall. Feeding MTO also decreased backfat thickness and increased belly firmness. Increasing vitamin E in diets containing MTO decreased drip loss percentage of the loin. These results indicate that MTO may function as a growth promoter; reduce backfat; and in conjunction with vitamin E, improve some aspects of meat quality.

(Key Words: Modified Tall Oil, Vitamin E, Growth Performance, Carcass Characteristics.)

Introduction

Modified tall oil is an oily coproduct resulting from the kraft (sulfate) paper process and contains high levels (~70%) of conjugated linoleic acid. Prior work at Kansas State University has shown MTO to be a potent carcass modifier in terms of reducing backfat and increasing carcass lean content. One of these earlier reports showed decreases in drip loss percentage resulting from feeding MTO. Thus, we postulated that MTO could be affecting membrane stability and(or) permeability. Furthermore, feeding elevated levels of vitamin E is a common method of trying to improve fresh pork color through its antioxidant properties. Therefore, this study was conducted to determine if feeding MTO and elevated levels of vitamin E would improve growth performance and carcass characteristics, as well as drip loss percentage and fresh pork color in finishing weight barrows.

Procedures

Procedures used in this experiment were approved by the Kansas State University Institutional Animal Care and Use Committee (Protocol No. 1480). A total of 72 crossbred barrows (initially 100 lb; PIC L326 or 327 × C22, Franklin, KY) were used. Pigs were blocked on the basis of initial weight and ancestry and randomly allotted to one of six dietary treatments with six replicate pens per treatment. Previously, pigs had been fed diets containing about 40,000 IU/ton of vitamin E from weaning (21 days of age) to 50 lb and 32,000 IU/ton from 50 to 100 lb.

Diets were fed in meal form in two phases (100 to 180 and 180 to 260 lb; Table 1). Modified tall oil and vitamin E were substituted on an equal weight basis for cornstarch to achieve the experimental diets, which were arranged in a 2 × 3 factorial

[1]Appreciation is expressed to Hercules, Inc., Wilmington, DE, for providing the modified tall oil used in this experiment and to Errol Bassoo of St. Joseph's Health Centre, London, Ontario, Canada, for analyzing the diets and longissimus samples for vitamin E content.

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design with two levels of MTO (0 or 0.50%) and three levels of added vitamin E (0, 20,000, or 100,000 IU/ton). Dietary additions of vitamin E were made with dl-∝-tocopherol acetate. The vitamin premix typically used in diets manufactured at Kansas State University was modified so that it did not contain any vitamin E; thus, the only vitamin E present in the basal diets was that contributed by the corn and soybean meal. All diets were analyzed for vitamin E content (Table 2). This analysis showed that the corn and soybean meal used in this study contributed 12,700 to 15,000 IU of vitamin E per ton. Bioavailability of the vitamin E found in corn and soybean meal is assumed to be low. Using ADFI in Table 3, a mean vitamin E intake/day was calculated. As expected, vitamin E intakes were dramatically increased with increasing level of dietary vitamin E.

Pigs were housed in an environmentally controlled finishing barn with two pigs in each 4 ft × 4 ft totally slatted-floored pen. They were allowed ad libitum access to feed and water through one single-hole self-feeder and a nipple waterer. Pigs were weighed every 14 d in order to determine ADG, ADFI, and F/G.

Pigs were slaughtered when their average weight reached 260 lb. Standard carcass measurements; visual analyses of the longissimus muscle for coloring, marbling, and firmness; longissimus drip loss, and color spectrophotometry were determined for each pig at 28 h postmortem (drip loss = 48 h postmortem). During fabrication of the carcasses (26 h postmortem), the bellies from the right sides of all carcasses were removed and evaluated for firmness.

Data were analyzed as a randomized complete block. Pen was the experimental unit for all calculations. The GLM procedures of SAS were used for all analyses. The data were analyzed as a 2 × 3 factorial with main effects of MTO (0 or 0.50% of the total diet) and vitamin E (0, 20,000, or 100,000 IU added vitamin E/ton of feed). The statistical model included main effects and interactions of the main effects. Hot carcass weight was used as a covariate in the statistical model for carcass analyses. Belly weights and lengths were used as covariates in the statistical model for belly firmness analyses.

Results and Discussion

Growth Data. From 100 to 180 lb, pigs fed diets containing MTO grew faster (P = .03) and were more efficient (P = .09) than pigs fed diets that did not contain MTO regardless of vitamin E level (Table 3). Dietary treatment did not affect (P>.15) growth performance from 180 to 260 lb or for the overall trial.

Carcass Characteristics. Feeding MTO, regardless of level of vitamin E, reduced (P<.01) average backfat (Table 4); similar responses were observed for the constituent components of average backfat (first and last rib and last lumbar backfat). Three interactions of MTO and vitamin E were observed for the longissimus muscle. Adding increasing levels of vitamin E to diets containing MTO increased firmness (P=.04) and marbling (P=.07) of the longissimus muscle and decreased (P=.02) drip loss percentage compared to increasing levels of vitamin E but not MTO. Other carcass characteristics such as shrink loss, dressing percentage, longissimus muscle color, calculated lean percentage, and longissimus muscle area (LMA) were not affected (P>.10) by dietary treatment. Modified tall oil increased belly firmness, both initially (P=.01) and at 1- and 5- minute intervals (P<.05), regardless of level of vitamin E.

Similar to prior reports, feeding MTO did not seem to permanently improve or change growth performance; thus, its effects on carcass composition are not related to changes in growth rate or food intake.

Some aspects of the interpretation of data were made difficult by the quality of the pigs fed the control diet with neither MTO nor additional vitamin E. The three interactions of MTO and vitamin E observed in carcass characteristics are difficult to explain because adding vitamin E to diets not contain-

ing MTO decreased marbling and firmness and increased drip loss, whereas adding vitamin E to diets containing MTO improved these same characteristics. However, the best quality for these three traits generally occurred for the group of pigs fed neither feed additive. This may have been because of the high vitamin E content of the diets fed to the pigs before this experiment was started. Feeding elevated levels of vitamin E without MTO worsened (P<.05; Table 4) b* and saturation index values, whereas feeding elevated levels of vitamin E with MTO improved these same two values. The difference in saturation index values indicates a more brightly colored product from feeding the combination of MTO and vitamin E, and the improvements in b* values may indicate a delay in intramuscular marbling lipid oxidation. Results of a study with rats (pg. 143) indicate that MTO facilitates the incorporation of vitamin E into adipose tissues. This would have profound effects on meat quality in terms of increasing shelf-life and decreasing off-flavors associated with lipid oxidation. However, feeding increasing levels of vitamin E did not increase (P>.15) incorporation of vitamin E into longissimus tissue (Table 3). The extra vitamin E was either being excreted or deposited elsewhere in the body.

These results indicate that feeding MTO may improve growth performance and will decrease backfat and increase belly firmness in crossbred finishing barrows. Feeding a combination of high levels of vitamin E and MTO may improve some aspects of meat quality. Furthermore, feeding the combination of MTO and vitamin E also may remove some of the inconsistencies typically observed in meat quality from feeding elevated levels of vitamin E alone.

Table 1. Compositions of Basal Diets (As-Fed Basis)

Ingredient, %	Growing (180 to 180 lb)	Finishing (180 to 260 b)
Corn	68.76	78.08
Soybean meal (46.5% CP)	27.50	18.43
Limestone	1.05	.88
Cornstarch[a]	1.00	1.00
Monocalcium phosphate	.86	.78
Salt	.35	.35
Vitamin premix[b]	.20	.20
Trace mineral premix	.15	.15
Antibiotic[c]	.13	.13
Total	100.00	100.00
Calculated analysis, %		
Lysine	1.00	.75
Calcium	.65	.55
Phosphorus	.55	.50

[a]MTO and vitamin E were substituted on an equal weight basis for cornstarch to give the additional dietary treatments.
[b]The vitamin premix did not contain any vitamin E.
[c]Provided 100 g/ton tylosin.

Table 2. Analyzed Vitamin E Contents of Diets and Daily Vitamin E Intakes

	0 MTO + Vit. E, IU/ton			.50% MTO + Vit. E, IU/ton		
Item	0	20,000	100,000	0	20,000	100,000
100 to 180 lb						
Dietary E, IU/ton	12,701	40,642	89,359	13,154	36,741	81,466
E intake, mg/d	41	131	284	42	123	261
180 to 260 lb						
Dietary E, IU/ton	14,969	35,834	91,627	14,515	38,284	87,091
E intake, mg/d	59	147	370	57	159	341

Table 3. Growth Performance of Pigs Fed Increasing Levels of MTO or Vitamin E[a]

	0 MTO + Vit. E, IU/ton			.50% MTO + Vit. E, IU/ton				Probability Values (P =)		
Item	0	20,000	100,000	0	20,000	100,000	CV	MTO × E	MTO	E
100 to 180 lb										
ADG, lb	2.56	2.58	2.60	2.63	2.74	2.70	5.32	.68	.03	.51
ADFI, lb	6.41	6.47	6.35	6.41	6.67	6.41	4.20	.68	.34	.20
F/G	2.51	2.52	2.45	2.44	2.44	2.38	4.90	.98	.09	.39
180 to 260 lb										
ADG, lb	2.45	2.55	2.40	2.38	2.55	2.39	8.27	.90	.65	.16
ADFI, lb	7.92	8.20	8.07	7.87	8.30	7.82	7.39	.77	.73	.29
F/G	3.24	3.22	3.36	3.32	3.27	3.28	4.85	.45	.73	.48
100 to 260 lb										
ADG, lb	2.51	2.56	2.50	2.51	2.64	2.55	5.06	.75	.33	.18
ADFI, lb	7.17	7.33	7.20	7.14	7.48	7.12	5.37	.75	.93	.21
F/G	2.86	2.86	2.88	2.85	2.83	2.79	3.57	.60	.22	.92

[a]Values are means of two pigs per pen and six replicate pens per dietary treatment.

Table 4. Carcass Characteristics of Pigs Fed Increasing Levels of MTO or Vitamin E[a,b]

	0% MTO + Vit. E, IU/ton			.50% MTO + Vit. E, IU/ton				Probability Values (P =)		
Item	0	20,000	100,000	0	20,000	100,000	CV	MTO × E	MTO	E
Shrink loss, %	1.90	1.81	1.83	1.94	2.02	1.91	10.66	.77	.21	.71
Dressing %	74.99	75.13	75.23	75.24	75.44	74.98	1.14	.72	.93	.97
Backfat, in										
First rib	1.60	1.55	1.48	1.42	1.50	1.48	6.64	.13	.03	.57
Last rib	1.07	1.02	.98	.95	.98	.92	7.90	.61	.004	.12
Last lumbar	.92	.90	.85	.83	.86	.81	12.64	.92	.09	.43
10th rib	1.05	1.01	.98	.92	.98	.96	12.28	.52	.11	.89
Average[c]	1.19	1.16	1.10	1.07	1.12	1.07	6.13	.29	.004	.16
LMA, in^2	5.41	5.53	5.42	5.49	5.55	5.59	7.02	.65	.78	.90
Lean, %[d]	48.41	48.96	49.14	49.97	49.23	49.71	3.61	.65	.20	.90
Visual color[e]	2.54	2.25	2.08	2.29	2.29	2.46	15.85	.13	.59	.65
Firmness[e]	2.79	2.17	2.21	2.48	2.38	2.63	13.89	.04	.33	.09
Marbling[e]	2.38	2.08	2.08	2.17	2.13	2.50	14.17	.07	.43	.34
L*[f]	58.34	60.00	58.25	58.87	59.54	57.73	4.09	.83	.85	.20
a*[f]	9.47	10.21	10.87	10.55	9.98	10.28	10.77	.16	.81	.41
b*[f]	16.99	18.97	19.09	18.69	18.15	17.98	7.17	.03	.86	.33
Hue angle[f]	60.86	61.77	60.51	60.55	61.17	60.29	2.92	.96	.53	.33
Saturation index[f]	19.47	21.55	21.98	21.47	20.72	20.72	7.57	.04	.95	.38
a*/b*[f]	.56	.54	.57	.57	.55	.57	7.44	.95	.58	.32
630/580[f]	2.60	2.66	2.81	2.71	2.65	2.71	6.57	.40	.96	.26
Drip loss, %	3.05	5.12	3.93	4.71	4.37	3.46	27.87	.02	.97	.26
Belly firmness, in										
Initial	14.92	15.07	13.88	17.32	17.11	16.59	16.82	.93	.01	.59
1 min	13.53	13.32	12.38	14.63	15.42	14.65	18.10	.77	.04	.63
5 min	12.25	12.02	11.26	13.15	13.98	13.36	17.80	.73	.04	.69
Longissimus vitamin E content (µg/g)	10.92	12.33	11.25	8.42	11.17	7.83	51.00	.87	.19	.52

[a]Values are means of two pigs per pen and six replicate pens per dietary treatment. [b]Hot carcass weight was used as a covariate in the statistical model for carcass characteristics and belly weights and lengths were used as covariates in the statistical model for belly firmness. [c]Average backfat is the average of the first and last rib and last lumbar fat depths. [d]Lean percentage was derived from NPPC (1991) equations with 5% fat in the carcass. [e]Scale of 1 to 5: 2 = grayish pink, soft and watery, or traces to slight; 3 = reddish pink, slightly firm and moist, or small to modest; and 4 = purplish red, firm and moderately dry, or moderate to slightly abundant for color, firmness, and marbling, respectively. [f]Means were derived from two sample readings per loin. Measures of dark to light (L*), redness (a*), yellowness (b*), red to orange (hue angle), vividness or intensity (saturation index), and reflectance values (630/580).

INFLUENCE OF DIETARY SUPPLEMENTATION OF MODIFIED TALL OIL AND VITAMIN E ON PORK CHOP QUALITY, DISPLAY COLOR STABILITY, WARNER-BRATZLER SHEAR, AND SENSORY PANEL TRAITS

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Summary

Seventy-two crossbred (PIC) barrows were used to determine the influence of feeding modified tall oil (MTO, 0 or .5% of diet) and vitamin E (0, 10, or 50 IU/lb of feed) on display color stability, Warner-Bratzler shear, and sensory panel traits of pork chops. Feeding MTO in combination with high levels of vitamin E to pigs during both the growing and finishing phases improved display color stability and delayed lipid oxidation of the pork loin chops without affecting tenderness and sensory evaluations. Therefore, feeding swine MTO (.5%) with high levels of vitamin E (50 IU/lb of feed) can increase the shelf-life stability of pork and potentially reduce monetary losses from deteriorated product.

(Key Words: Modified Tall Oil, Vitamin E, Pork Chop.)

Introduction

Modified tall oil (MTO) is a by-product of the pulp and paper industry and has a high content of conjugated linoleic acid (66.6%). Supplementation of swine diets with MTO has decreased backfat, increased lean percentage, and increased belly firmness. Vitamin E is an effective lipid-soluble antioxidant that protects cell membranes from oxidation and deterioration. Feeding MTO to pigs may assist in the tissue absorption of vitamin E. Therefore, the combination of MTO and vitamin E potentially could improve pork quality characteristics through enhanced vitamin E uptake. The objective of this study was to determine the influence of diet supplementation of MTO and vitamin E on pork display and sensory characteristics.

Procedures

In a 2 × 3 factorial arrangement, 72 crossbred (PIC) barrows were blocked by initial BW (100 lb) and ancestry and randomly allotted to one of six dietary treatments. Two pigs were fed in each pen with six replicate pens per treatment. The main effects were two levels of MTO (0 or .5% of diet) and three levels of dl-α-tocopheryl acetate (0, NE; 10, LE; and 50 IU/lb of feed, HE). The corn-soybean meal-based growing diet was fed from 100 lb to 180 lb BW and was formulated to contain 1.0% lysine. The corn-soybean meal-based finishing diet was fed from 180 lb to 260 lb BW and was formulated to contain .75% lysine.

Pigs were harvested humanely using standard industry procedures approved by the Kansas State University Animal Care Committee. At 28 h postmortem, the right side of each carcass was fabricated into the wholesale cuts of ham, loin, belly, spareribs, and shoulder. From the wholesale loin, a 9-in. boneless loin was removed from the tenth rib and posterior, vacuum packaged, and aged for an additional 6 d at 39°F. At 7 d postmortem, each loin was faced at the tenth rib surface and cut into 1-in. chops. Cutting anterior to posterior, chops were assigned as follows: 1) display color, 2) 0 d thiobarbituric acid reacting substance (TBARS), 3)

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4 d TBARS, 4) sensory panel, and 5) Warner-Bratzler shear force (WBS).

Display chops were packaged in PVC film and displayed at 36°F under continuous lighting. Visual display color was evaluated by nine panelists trained according to meat color evaluation guidelines to the nearest .5. The 5-point color scale consisted of 1 = bright grayish-pink or reddish-pink, 2 = grayish-pink or reddish-pink, 3 = slightly dark pink/red to brown, 4 = moderately dark pink/red to brown, and 5 = dark pink/red to brown. A score of 3.5 indicated a point when the product had sufficient visual color deterioration to potentially be unsaleable. Instrumental spectral data for ratio of reflectance %R630/%R580 and CIE L*a*b* values were measured. Color was evaluated on 0, 1, 2, 4, 6, and 8 d of display.

The extent of lipid oxidation was measured as TBARS at 0 and 4 d of display. The 0-d TBARS chops were cut, immediately packaged, crust frozen at -40°F for 30 min, vacuum packaged, and stored at -40°F. The 4-d TBARS chops were displayed in the cases for 4 d as previously described and then stored at -40°F. Values for duplicate samples from each chop were averaged and expressed as mg malonaldehyde/kg DM.

The pork chops for WBS were thawed, weighed, and cooked to an internal temperature of 160°F in a Blodgett dual-air-flow oven. Chops were cooled at room temperature (70°F) for 1 h, reweighed, and subsequently chilled before six .5-in. diameter cores were removed parallel to the muscle fibers and sheared perpendicular to the muscle fibers using a WBS attachment on an Instron Universal Testing Machine. Percentages of thawing and cooking losses were calculated.

The pork chops for sensory evaluation were cooked to an internal temperature of 160°F. Chops were removed from the oven and immediately cut into cubes of .5 in. × .5 in.×cooked chop thickness. A trained seven-member descriptive attribute sensory analysis panel evaluated two samples from each chop. Six sensory traits of myofibrillar tenderness, connective tissue amount, overall tenderness, juiciness, flavor intensity, and off-flavor were evaluated on an 8-point scale.

The experimental design was a 2 × 3 factorial in a randomized complete block design using initial weight and ancestry to establish blocks. Statistical analyses were performed with the GLM procedure of SAS using the pen mean as the experimental unit. For comparisons pertaining to measurements over time, a split-plot analysis using the Mixed procedure of SAS was conducted to account for repeated measurements that included the fixed effects of treatment and display day. All main effect and interaction means were separated ($P<.05$) using the Least Significant Difference procedure when the respective F-tests were significant ($P<.05$).

Results and Discussion

An MTO × vitamin E × day of display interaction ($P = .02$) was observed for visual color (Figure 1). As expected, the visual panel color scores revealed a decline (increased score, $P<.01$) in fresh pork color over each day of display. At 0 and 1 d, no differences ($P>.05$) were observed among treatments. At 2 d, chops from pigs fed MTO with HE had lower ($P<.05$) color values (less deterioration) than chops from pigs fed MTO with NE. At 4 d, LM chops from pigs fed MTO with HE had less deterioration ($P<.05$) than chops from pigs fed MTO with NE, no MTO with LE, and no MTO with HE. In addition, chops from pigs fed no MTO with NE and MTO with LE had less deterioration ($P<.05$) than chops from pigs fed MTO with NE. At 6 d, chops from pigs fed MTO with HE had less deterioration ($P<.05$) than chops from pigs fed MTO with NE, no MTO with NE, no MTO with LE, and no MTO with HE. Also, chops from pigs fed MTO with LE, no MTO with NE, and no MTO with HE had less deterioration ($P<.05$) than chops from pigs fed MTO with NE. At 6 d, the MTO with HE combination was the only treatment that sustained a mean score less than 3.5. A score of 3.5 or less indicates acceptable display color that should not be discounted in a typical retail case. At 8 d,

chops from pigs fed MTO with HE had less deterioration (P<.05) than chops from all other treatments. Additionally, chops from pigs fed MTO with LE and no MTO with HE had less deterioration (P<.05) than chops from pigs fed MTO with NE. Overall, feeding pigs MTO with HE delayed pork chop display color deterioration.

Instrumental display data are presented as MTO × vitamin E interaction means in Table 1. Day of display main effect means for chop display values are presented in Table 2. The chop display L* values were similar (P = .54) for pigs fed MTO (56.92) and no MTO (57.33). The vitamin E × day of display interaction (P<.001) means for CIE L* values are presented in Figure 2. At 0, 1, 2, and 4 d of display, no differences (P>.05) for L* were observed among levels of vitamin E. At 6 and 8 d of display, chops from pigs fed HE had lower (P<.05) L* values (were darker) than chops from pigs fed NE or LE. Overall, a darker color was maintained over the display period for chops from pigs fed HE. This may be associated with the visual color stability observed in chops from pigs fed MTO with HE.

The chop display a* values, an indication of redness, were similar (P = .76) for chops from pigs fed MTO (7.05) and no MTO (6.96). However, chops from pigs fed HE (7.47) had higher (P<.05) a* values than chops from pigs receiving NE (6.52). Overall, a* values declined as days of display increased. For b* values, an indication of yellowness, no differences (P > .10) were detected among treatments. Display b* values were higher early in the display period (0-2 d) than later (4-8 d).

An MTO × vitamin E interaction (P<.05) was detected for display ratio of reflectance values (Table 1). A higher (P<.05) ratio of reflectance (indicator of more oxymyoglobin) was observed for chops from pigs fed MTO with HE than chops from pigs fed no MTO with LE, no MTO with HE, and MTO with NE. Also, chops from pigs fed MTO with LE and no MTO with NE had higher (P<.05) ratio values than chops from pigs fed MTO with NE. Ratio of reflectance values for chops decreased (P<.05) at each evaluation period. The highest numerical ratio of reflectance indicated that feeding pigs MTO with HE may result in a higher ratio of oxymyoglobin to metmyoglobin. A higher oxymyoglobin concentration would be associated with a more desirable bright reddish-pink color (less deterioration).

An interaction of MTO × vitamin E was detected (P<.05) for TBARS, which is an indicator of lipid oxidation (Table 1). The chops from pigs fed MTO with HE had numerically the lowest values and had lower (P<.05) TBARS values than chops from pigs fed MTO with NE. The TBARS values of chops at 0 d were lower (P<.05) than those of chops displayed for 4 d (Table 2).

Sensory panel and WBS traits are given in Table 3. No differences (P>.05) were detected for these palatability-related traits.

Feeding pigs MTO with high levels of vitamin E appears to preserve the integrity and delay oxidation of cellular components. As a result, display color stability of pork chops is improved.

Figure 1. Influence of Modified Tall Oil, Vitamin E Supplementation, and Day of Display on Visual Color Scores of Pork Loin Chops (NE = no MTO, no vitamin E; LE = no MTO, 10 IU/lb vitamin E; HE = no MTO, 50 IU/lb vitamin E; MNE = MTO, no vitamin E; MLE = MTO, 10 IU/lb vitamin E; MHE = MTO, 50 IU/lb vitamin E).

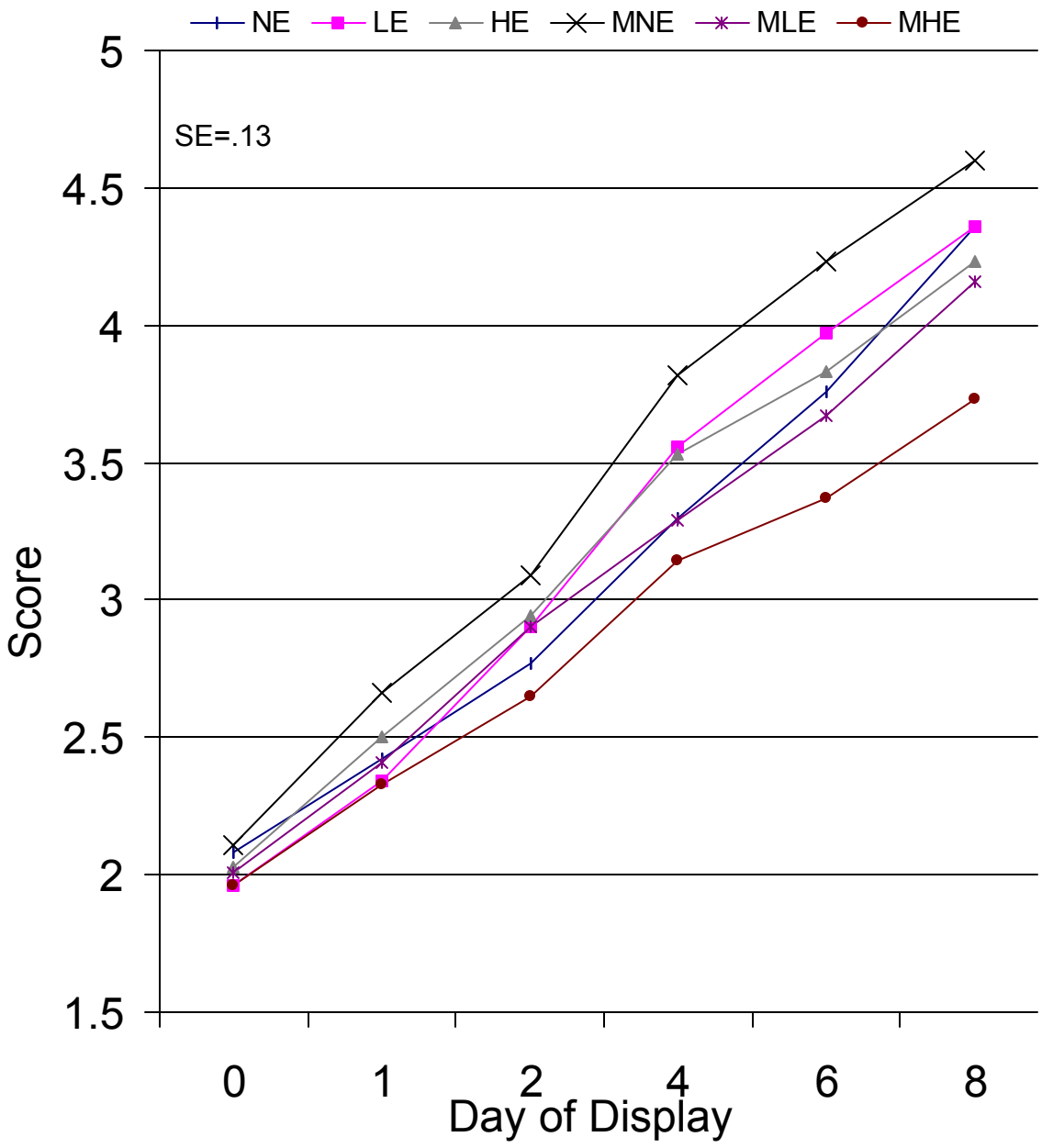

Figure 2. Influence of Vitamin E Supplementation and Day of Display on L* Values of Pork Loin Chops (NE = no vitamin E; LE = 10 IU/lb vitamin E; HE = 50 IU/lb vitamin E).

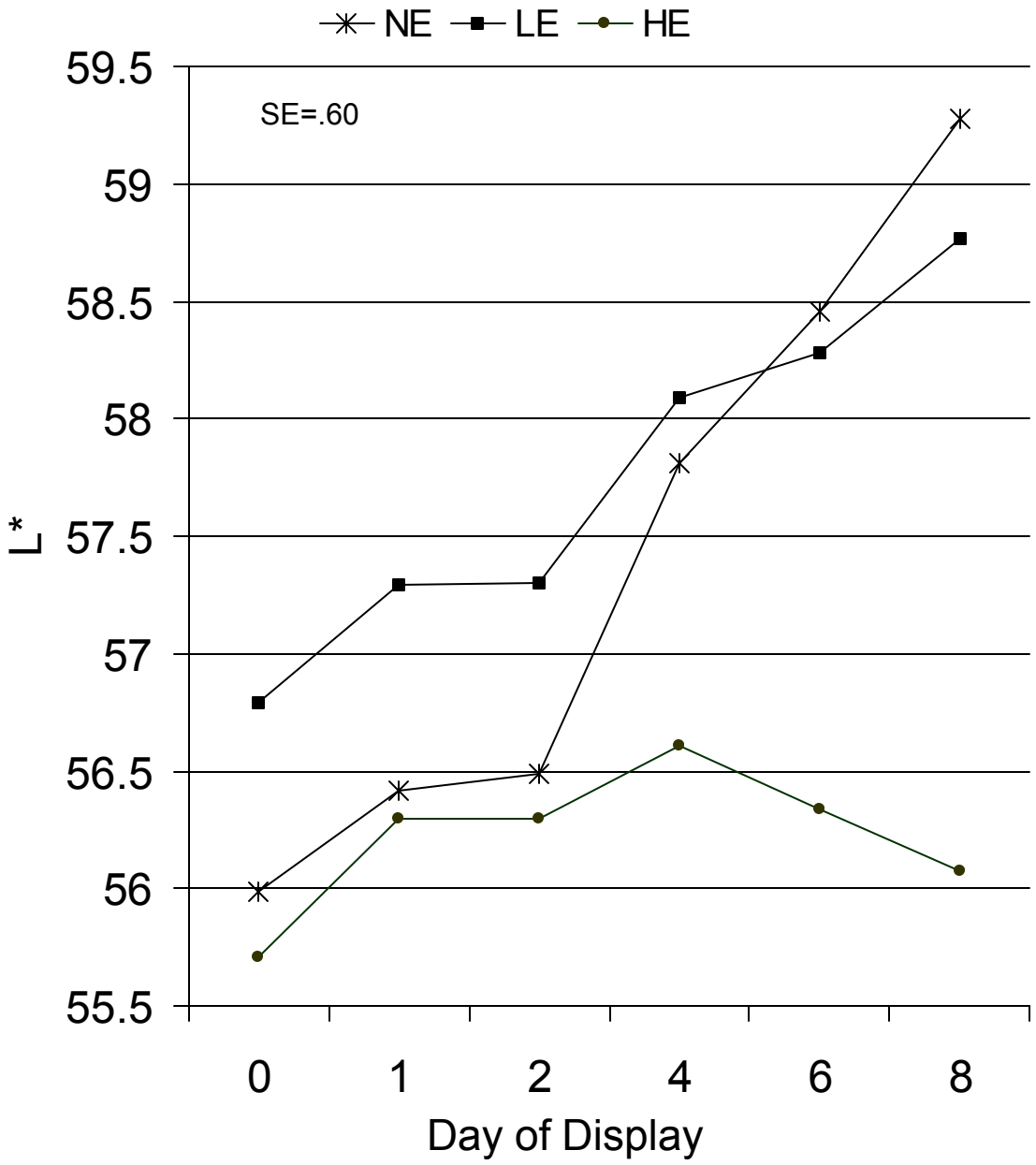

Table 1. Influence of Modified Tall Oil and Vitamin E Supplementation on Display Instrumental Color and TBARS[e] Measurements of Pork Loin Chops

	Supplementation[a]						
MTO, %	0	0	0	.5	.5	.5	
Item Vit. E	0	10	50	0	10	50	SE
Instrumental Color[b]							
L*[c]	56.50	58.57	56.93	58.32	56.93	55.52	.80
a*[d]	6.86	6.98	7.05	6.19	7.05	7.90	.32
b*	20.22	20.65	20.36	20.18	20.45	20.33	.21
%R630/%R580	2.11^{gh}	2.00^{fg}	2.07^{fg}	1.92^{f}	2.13^{gh}	2.25^{h}	.06
TBARS[e]	3.11^{fg}	3.18^{fg}	3.18^{fg}	3.41^{g}	3.07^{fg}	2.86^{f}	.10

[a]MTO = Modified tall oil and Vit. E = dl-α-tocopheryl acetate/lb feed.
[b]Measure of lightness (L*), redness (a*), yellowness (b*), vividness or intensity (saturation index), or indicator of the amount of oxymyoglobin present (ratio of reflectance %R630/%R580).
[c]Vitamin E × day of display interaction (See Figure 2).
[d]Pigs fed 50 IU vitamin E/lb of feed had higher ($P < .05$) values than pigs fed no vitamin E.
[e]Thiobarbituric acid reacting substance, mg malonaldehyde/kg DM.
[f,g,h]Means in the same row with a different superscript letter differ ($P < .05$).

Table 2. Influence of Day of Display on Instrumental Color and TBARS[c] Measurements of Pork Loin Chops

	Day						
Item	0	1	2	4	6	8	SE
Instrumental Color[a]							
L*[b]	56.16	56.67	56.70	57.50	57.69	58.04	.34
a*	8.66^{h}	8.37^{h}	7.63^{g}	7.45^{f}	5.77^{e}	4.15^{d}	.22
b*	21.50^{h}	21.12^{g}	20.60^{f}	19.30^{d}	19.61^{d}	20.06^{e}	.20
%R630/%R580	2.79^{d}	2.47^{e}	2.23^{f}	1.84^{g}	1.66^{h}	1.48^{i}	.04
TBARS[c]	.19^{d}	--	--	1.10^{e}	--	--	.11

[a]Measure of lightness (L*), redness (a*), yellowness (b*), or indicator of the amount of oxymyoglobin present (ratio of reflectance %R630/%R580).
[b]Vitamin E × day of display interaction (See Figure 2).
[c]Thiobarbituric acid reacting substance, mg malonaldehyde/kg dry matter.
[d,e,f,g,h,i]Means in the same row with a different superscript letter differ ($P < .05$).

Table 3. Influence of Modified Tall Oil and Vitamin E Supplementation on Pork Cookery, Warner-Bratzler Shear and Sensory Panel Evaluations

	Supplementation[a]						
MTO, %	0	0	0	.5	.5	.5	
Item Vit. E	0	10	50	0	10	50	SE
Thawing loss, %	2.57	2.72	2.92	2.69	2.61	2.74	.19
Cooking loss, %	25.23	27.22	27.63	26.79	25.67	27.10	.92
Shear force, lb	5.64	6.26	6.83	6.66	6.44	6.15	.17
Sensory Evaluation[b]							
Myofibrillar tenderness	6.43	6.16	5.86	6.14	6.02	6.26	.16
Connective tissue	7.59	7.55	7.47	7.65	7.57	7.60	.07
Overall tenderness	6.55	6.32	6.01	6.30	6.25	6.44	.16
Juiciness	5.33	5.21	5.25	5.35	5.15	5.32	.12
Flavor intensity	5.67	5.72	5.74	5.69	5.67	5.69	.06
Off-flavor	7.79	7.83	7.82	7.82	7.85	7.91	.07

[a]MTO = Modified tall oil and Vit. E = dl-α-tocopheryl acetate/lb feed.

[b]Scores of 1 to 8: myofibrillar/overall tenderness (5 = slightly tender, 6 = moderately tender, 7 = very tender); connective tissue (7 = practically none, 8 = none); juiciness (4 = slightly dry, 5 = slightly juicy); flavor intensity (5 = slightly intense, 6 = moderately intense); off-flavor (7 = practically none, 8 = none).

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INFLUENCE OF DIETARY SUPPLEMENTATION OF MODIFIED TALL OIL AND VITAMIN E ON BACON CHARACTERISTICS

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Summary

Seventy-two crossbred (PIC) barrows were used to determine the influence of feeding modified tall oil (MTO, 0 or .5% of diet) and vitamin E (0, 10, or 50 IU/lb of feed) on bacon quality characteristics. Feeding MTO to pigs during both the growing and finishing phases increased bacon slice firmness. Feeding swine MTO and vitamin E had minimal effects on bacon production, proximate analysis, and quality traits. Therefore, any of these combinations of MTO with vitamin E can be fed to swine to improve carcass traits without affecting bacon.

(Key Words: Modified Tall Oil, Vitamin E, Bacon.)

Introduction

Modified tall oil is a by-product of the pulp and paper industry and has a high content of conjugated linoleic acid (66.6%). Supplementation of swine diets with MTO has decreased backfat, increased lean percentage, and increased belly firmness. Vitamin E is an effective lipid-soluble antioxidant that protects cells membranes from oxidation and deterioration. Feeding MTO to pigs may assist in the tissue absorption of vitamin E. Therefore, the objective of this study was to determine the influence of diet supplementation of MTO and vitamin E in swine diets on production, proximate analysis, and quality characteristics of bacon.

Procedures

In a 2 × 3 factorial arrangement, 72 crossbred (PIC) barrows were blocked by initial BW (100 lb) and ancestry and randomly allotted to one of six dietary treatments. Two pigs were fed in each pen with six replicate pens per treatment. The main effects were two levels of MTO (0 or .5% of diet) and three levels of dl-α-tocopheryl acetate (0, NE; 10, LE; and 50 IU/lb of feed, HE). The corn-soybean meal-based growing diet was fed from 100 lb to 180 lb BW and was formulated to contain 1.0% lysine. The corn-soybean meal-based finishing diet was fed from 180 lb to 260 lb BW and was formulated to contain .75% lysine.

At 28 h postmortem, the right side of each carcass was fabricated into the wholesale cuts of ham, loin, belly, spareribs, and shoulder. Bellies were vacuum packaged and stored at -40°F until bacon manufacture, when they were thawed at 37°F for 72 h in their vacuum bags. The bellies were weighed and injected with a pickle (10% of the weight) using a multineedle pump injector and reweighed. The pickle was a standard curing mixture (13.2% salt, 7% sugar, 1% sodium nitrite, 2% maple sugar, and 76.8% water). Bellies were tumbled continuously for 4 h, weighed, and hung on bacon combs before cooking in a smokehouse. After attaining an average internal temperature of 147°F (approximately 2 h), bellies were weighed, skin was peeled, and bellies were

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reweighed and rehung. The bellies were placed back in the smokehouse, where they completed a drying cycle (1 1/4 h), were smoked for 1 1/2 h with 100% hickory wood sawdust, and were processed to an internal temperature of 135°F. Bellies were placed in a 37°F cooler for 40 h and reweighed. Percentages of belly thawing loss, pumping uptake, tumbling loss, cooking loss, and final yield were calculated.

Cured bellies were cut into .16-in. bacon slices. Twelve slices at approximately one-third the length of the bacon slab from the cranial end were obtained for analysis. Slices were evaluated for firmness and number of holes. Firmness was evaluated on a scale from 1 = very soft and oily to 8 = very brittle and crumbly. Number of holes was ranked on a scale of 1 = very high number to 8 = none.

Two slices of bacon were frozen at -40°F and pulverized in a Waring Blender. Samples were analyzed for percent extractable lipid and moisture using AOAC (1992) procedures.

The experiment was a 2 × 3 factorial in a randomized complete block design using initial weight and ancestry to establish blocks. Statistical analyses were performed with the GLM procedure of SAS using the pen mean as the experimental unit. All main effect and interaction means were separated ($P<.05$) using the Least Significant Difference procedure when the respective F-tests were significant ($P<.05$).

Results and Discussion

Bacon production, proximate analysis, and quality traits are presented in Table 1. Percentages of lipid and moisture, thaw loss, tumbling loss, cook loss, and final yield did not differ ($P>.10$) among treatments. Bellies from pigs fed MTO (8.43%) had lower ($P<.05$) pump uptake percentages than bellies from nonsupplemented pigs (9.43%).

An MTO × E interaction ($P = .02$) occurred; bacon from pigs fed MTO with LE had firmer ($P<.05$) slices than bacon from pigs fed no MTO with HE and MTO with NE. Also, bacon from pigs fed MTO with LE, MTO with HE, and no MTO with NE had firmer ($P<.05$) slices than bacon from pigs fed no MTO with HE. No differences ($P>.05$) were detected for the number of holes in the bacon slices. Overall, the combination of MTO and vitamin E did not influence production characteristics of bacon but may have contributed somewhat to improved firmness. Previous research reported that fresh bellies from pigs fed .5% MTO were firmer than bellies from pigs fed no MTO. Overall, MTO and vitamin E supplementation appears to have minimal effects on bacon. Therefore, producers probably can feed MTO with vitamin E for improved carcass traits without influencing bacon quality characteristics.

Table 1. Influence of Modified Tall Oil and Vitamin E Supplementation on Production, Proximate Analysis, and Quality Traits of Bacon

	Supplementation[a]						
MTO, %	0	0	0	.5	.5	.5	
Item Vit. E	0	10	50	0	10	50	SE
Production Characteristics							
Thawing loss, %	.96	1.79	1.38	1.14	1.13	1.34	.22
Pump uptake, %[b]	9.15	9.15	9.97	8.17	8.61	8.51	.38
Tumbling loss, %	2.35	2.48	2.70	2.75	2.12	2.90	.27
Cooking loss, %	21.80	22.66	22.08	23.75	22.83	22.81	1.01
Final yield, %	83.54	82.22	84.02	80.49	82.46	81.43	1.32
Proximate Analysis							
Moisture, %	46.19	46.84	46.65	46.71	46.34	47.15	1.37
Fat, %	35.46	34.02	35.33	33.54	35.14	33.44	1.91
Quality Evaluations							
Slice firmness[c]	5.25^{fg}	5.00^{efg}	4.54^{e}	4.92^{ef}	5.58^{g}	5.38^{fg}	.21
Slice holes[d]	7.21	7.00	6.50	7.04	6.96	7.17	.19

[a]MTO = Modified tall oil and Vit. E = IU d, l á-tocopheryl acetate/lb feed.

[b]Pigs fed .5% MTO had lower (P<.05) values than pigs not fed MTO.

[c]Scores of 1 to 8: 1 = very soft oily; 8 = very brittle and crumbly.

[d]Scores of 1 to 8: 1 = high number of holes; 8 = no holes.

[e,f,g]Means in the same row with a different superscript letter differ (P<.05).

EFFECTS OF MODIFIED TALL OIL ON GROWTH AND BODY COMPOSITION IN ADULT OVARIECTOMIZED RATS[1]

P. R. O'Quinn, S. I. Koo[2], S. K. Noh[2], J. L. Nelssen, R. D. Goodband, and M. D. Tokach[3]

Summary

A trial was conducted to evaluate the effects of modified tall oil (MTO) on growth and body composition of adult ovariectomized rats. This trial was targeted as a model for postmenopausal women; thus, only data applicable to swine production are presented herein. Feeding MTO decreased adiposity, increased concentrations of certain lipids in tissues, increased vitamin E (∝-tocopherol) levels in the adipose, and increased actual lean content. These data lend support to the carcass leanness and meat quality improvements routinely seen in swine from feeding MTO.

(Key Words: Rats, Modified Tall Oil, Vitamin E, Conjugated Linoleic Acid.)

Introduction

Modified tall oil is an oily coproduct from the kraft (sulfate) paper process and contains relatively high amounts (~70%) of conjugated linoleic acid. Work in pigs has shown that MTO is a potent carcass modifier in terms of reducing backfat and increasing lean percentage. However, all work with MTO has been conducted with young growing pigs up to market weight and slaughter at 235 to 260 lb BW. The observed reductions in backfat coupled with increases in lean content would be of tremendous interest in humans, but especially in post-menopausal women. These women are typically beset with increases in adiposity and particularly an increased susceptibility to abdominal fat gains. The potential uses of MTO would be expanded dramatically if it could be shown to reduce adiposity in a model representing postmenopausal women. Additionally, prior research has shown that MTO alters the metabolism of vitamin E. Vitamin E is taken routinely as an antioxidant and dietary supplement for people. Therefore, the current experiment was undertaken to investigate the roles of MTO in growth and body composition in a rat model used to mimic postmenopausal women.

Procedures

Procedures used in this experiment were approved by the Kansas State University Institutional Animal Care and Use Committee (Protocol No. 1531). A total of 26 adult female Sprague-Dawley rats (initially 256.8 g BW; Harlan Sprague Dawley, Indianapolis, IN) was used. Rats were blocked on the basis of initial weight and assigned to one of two dietary groups with 13 rats per group.

The basal diet was purchased from a commercial supplier and fortified with zinc carbonate to achieve a Zn level of 32 ppm. This diet was fed from the time the rats arrived until the initiation of the test. The basal diet was modified as follows to achieve the two experimental diets (Table 1). An oil

[1]Appreciation is expressed to Hercules, Inc., Wilmington, DE, for providing the modified tall oil used in this experiment; and to Dr. Bob Teeter of Oklahoma State University, Stillwater, OK, for assistance in obtaining the body composition and respiratory measurements on the rats used in this study.

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mixture (soybean oil and fatty acids or MTO and fatty acids) was included at 1% of the total diet. The fatty acid profiles of the MTO and soybean oil were determined so that diets could be matched in fatty acid profile. This ensured that any biological responses observed in the trial were attributable only to the conjugated linoleic acid isomers present in MTO. Both oil mixtures contained 6.9 mg vitamin E (∝-tocopherol)/100 g of oil mixture.

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

Ingredient	Percent
Egg white	20.00
Cornstarch	39.65
Dextrinized cornstarch	13.20
Dextrose	10.00
∝-Tocopherol-stripped soybean oil	7.00
Cellulose	5.00
Mineral mix[b]	3.50
Vitamin mix	1.00
Biotin (1 mg/g biotin sucrose mix)	.40
Choline bitartrate	.25

[a]The two experimental diets were made by adding either 1% soybean oil mixture (containing 2.98% oleic acid, 17.18% linoleic acid, and 79.84% ∝tocopherol-stripped soybean oil) or 1% MTO mixture (containing 9.0% palmitic acid, 4.5% stearic acid, 7.8% linolenic acid, and 78.70% MTO) to the purchased diet, which was fed during the adaptation and recovery periods only. The fatty acid additions were necessary to balance each diet in fatty acid profiles. Pure ∝-tocopherol was added to each oil mixture at the rate of 6.9 mg/100 g of oil mixture.
[b]As purchased, the mineral mix was Zn-free. Zinc carbonate was added to the diet to achieve a Zn level of 32 ppm.

Rats were placed individually in plastic cages with stainless-steel wire bottoms and given a 12-h light:dark cycle. These cages were housed in a laboratory accredited by the American Association for the Accreditation of Laboratory Animal Care. Rats were ovariectomized and given a recovery period prior to the initiation of the trial. Rats were trained to feed at certain times after the final determination of ad libitum intake. Thus, rats were pair fed twice daily for the duration of the 6-week trial at the rate of 90% of determined ad libitum intake (15 g/d; 6 g at 0900 and 9 g at 1630) and were offered free access to deionized water through a stainless-steel nipple watering system. Rats were weighed weekly to determine gain and efficiency of gain.

Six rats per group (randomly selected) were euthanized at 6 weeks for the collection of brain, heart, kidneys, liver, gastrocnemius muscle, and retroperitoneal and abdominal fat pads to determine cholesterol, phospholipids, and ∝-tocopherol levels. These data are not reported herein. Additionally, six rats per group (randomly selected) were transported to Oklahoma State University and allowed to adapt to respiration chambers. Once respiration rates stabilized, a respiration study for 44 h without food began. These data also are not reported herein. Upon termination of the respiration measurements, rats were euthanized and scanned via dual energy X-ray absorptiometry (DEXA) to determine body composition (fat, fat-free, and bone mineral contents).

Data were analyzed using paired *t*-tests. Individual rats were the experimental units for all observations.

Results and Discussion

By 3 weeks, rats fed MTO had reduced ($P<.05$) body weight; this trend continued for the duration of the 6-week trial (Figure 1). Rats were pair-fed, thus, potential differences from feed intakes were not a factor. Feed refusals were not observed in the current study, and rats quickly consumed their meals. This decrease in body weight gain from feeding MTO would be an advantage to postmenopausal women. Conjugated linoleic acid, which comprises about 70% of MTO, is known to influence growth depend-

ent upon the type of animal used. Thus, it is not surprising that MTO can be used to promote growth and carcass leanness in growing swine, but also slow body weight gain and adiposity in adult ovariectomized rats.

The rats (randomly selected) for body composition analyses were similar (P = .35) in weight (Table 2). Rats fed MTO had less fat, expressed either as total grams (P = .0001) or percentage (P = .0006). Rats fed MTO also had more fat-free mass, expressed either as total grams (P = .04) or percentage (P = .0007). On a percentage basis, rats fed MTO had about 21% less fat and about 5% more fat-free mass. Thus, the reduction in fat had the greatest impact on the improvements in leanness. This is in agreement with prior reports for pigs fed MTO. Bone mineral density and bone mineral content were not affected (P>.20) by dietary treatment, but the combined fat-free mass plus bone mineral content were higher (P = .07) for rats fed MTO.

Studies of pigs fed MTO also have shown increases in intramuscular marbling. In the current study, rats fed MTO had higher (P<.05) total cholesterol in the liver, kidneys, and fat depots and higher (P<.05) phospholipid content in the liver. Though no changes were observed in the muscle lipid content, these alterations may provide insight into the increases in intramuscular marbling routinely seen from feeding MTO to pigs.

A prior report with pigs demonstrated that feeding MTO in conjunction with elevated levels of vitamin E improved oxidation status and color and color stability of fresh pork. In the current study, rats fed MTO had enhanced ($P \leq .005$) vitamin E ($\propto$-tocopherol) levels in abdominal and retroperitoneal fat (134.11 vs 81.66 nmol/g and 128.51 vs 92.87 nmol/g for rats fed MTO and the control diet, respectively). This suggests that MTO preferentially shifts the deposition of vitamin E to the adipose tissues. Thus, fresh pork from pigs fed MTO should have improved display color characteristics because of the enhanced tissue incorporation of vitamin E.

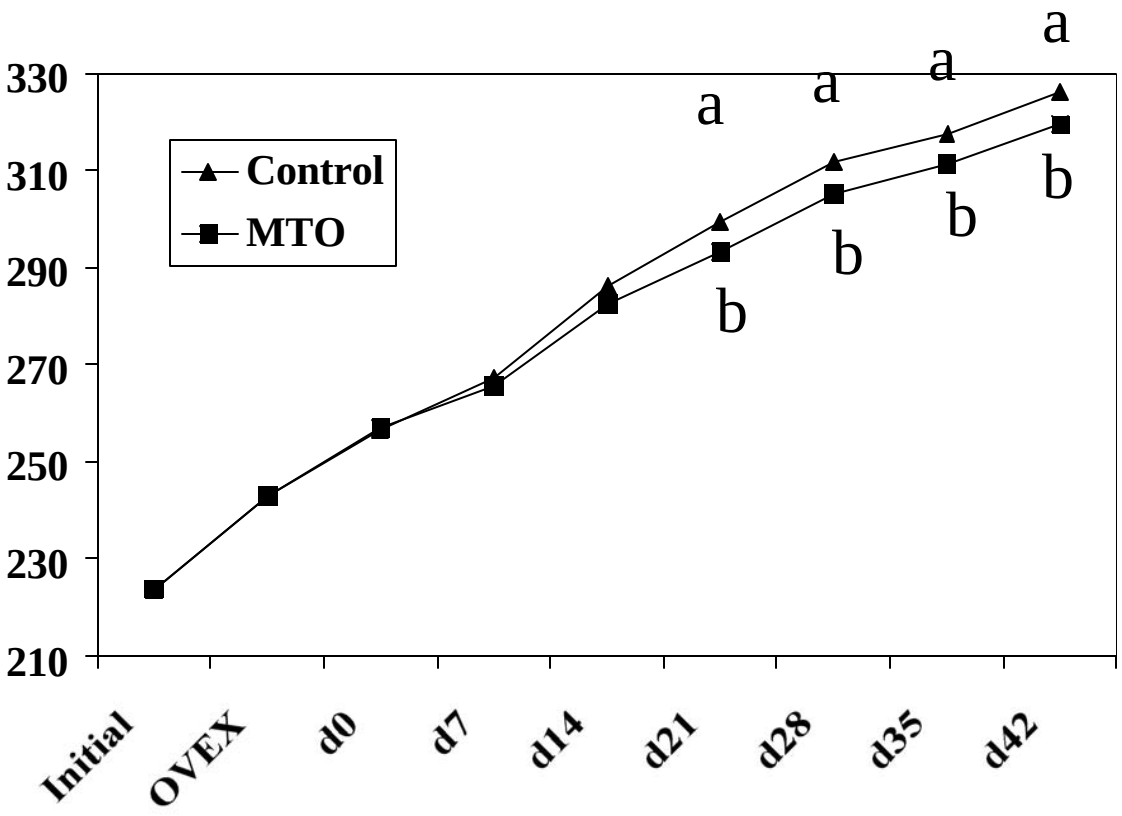
In summary, feeding MTO to rats used to model postmenopausal women elicits many favorable biological responses. Chief among them are the reductions in weight gain and fat deposition and increases in fat-free mass. These results can be extended to swine production and used to help explain the improvements in carcass leanness and color improvements seen from feeding MTO to pigs.

Table 2. Body Composition of Rats Fed MTO[a]

	Dietary Group		Probability Value
Item	Control	MTO	(P =)
Body weight, g	293.82 ± 4.22	295.90 ± 12.37	.35
Bone mineral content (BMC), g	7.31 ± .26	7.24 ± .21	.32
Fat, g	54.02 ± 2.22	43.05 ± 3.93	.0001
Fat-free, g	232.50 ± 6.09	245.72 ± 14.50	.04
Fat-free + BMC, g	239.80 ± 6.13	252.97 ± 14.59	.07
Fat, %	18.40 ± .96	14.57 ± 1.72	.0006
Fat-free, %	79.12 ± 1.00	82.96 ± 1.75	.0007
Bone mineral density, g/cm^2	.137 ± .003	.136 ± .002	.24

[a]Values are means for 6 rats per dietary treatment group.

Figure 1. Weekly Body Weights (g) of Rats Fed MTO. Values are means of 13 rats/group; a and b indicate values significantly different at P ≤ .07.



Swine Day 1999

EFFECTS OF MODIFIED TALL OIL AND SUPPLEMENTAL MAGNESIUM ON GROWTH PERFORMANCE, CARCASS CHARACTERISTICS, AND MEAT QUALITY OF GROWING-FINISHING GILTS[1]

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

Summary

A trial was conducted to evaluate the effects of feeding modified tall oil (MTO) and supplemental magnesium (Mg) on growth performance, carcass characteristics, and meat quality of finishing gilts. No effect of treatment was observed on ADG, ADFI, or F/G during the growth trial. Feeding MTO reduced average backfat and increased intramuscular marbling, whereas supplemental Mg reduced first rib backfat (but not average backfat) and postmortem levels of glycogen in the longissimus muscle. Additionally, Mg altered whole blood metabolic profiles in a manner that should improve meat quality, although improvements in pH, drip loss, and color were not observed in this trial.

(Key Words: Gilts, Modified Tall Oil, Magnesium, Meat Quality.)

Introduction

Modified tall oil has been shown previously to improve carcass leanness and potentially growth performance of growing-finishing pigs. Additional studies have shown that MTO positively influences display color stability, potentially by altering the way vitamin E is absorbed into the tissues. Recent work from Australia has shown that short-term administration of large doses of supplemental Mg fed to pigs about a week prior to slaughter improve fresh pork color and decrease drip loss percentage. Therefore, this trial was conducted to determine if feeding MTO and Mg together was a viable method for improving growth performance, carcass characteristics, and meat quality in crossbred growing-finishing gilts.

Procedures

Pigs used in this experiment were terminal offspring of PIC L326 or 327 boars × C22 sows (PIC, Franklin, KY). Experimental procedures were approved by the Kansas State University Institutional Animal Care and Use Committee (Protocol No. 1593).

A total of 80 crossbred gilts (initially 101 lb BW) was used in this study. Pigs were blocked on the basis of initial weight and ancestry in a randomized complete block design and randomly allotted to one of four dietary treatments arranged as a 2 × 2 factorial with 10 replicate pens per treatment. Two of the four dietary treatments were not implemented until 7 days preslaughter; thus, there were 20 pens per dietary treatment until the Mg supplementation began.

Diets were fed in meal form in two phases (101 to 168 and 168 to 260 lb BW; Table 1). The preselected pens of pigs were changed to the Mg-supplemented diets at 7 days preslaughter. At this time, pigs averaged 252 lb BW. Modified tall oil was

[1]Appreciation is expressed to IMC Agrico Feed Ingredients, Bannockburn, IL, for providing the potassium magnesium sulfate (DYNAMATE®) and for partial financial support of this experiment; to Hercules, Inc., for providing the modified tall oil; and to Colin Bradley of the London Health Sciences Centre, London, Ontario, Canada, for conducting the serum magnesium analyses.

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

substituted on an equal weight basis for soybean oil and $KMgSO_4$ was substituted on an equal weight basis (2% of the total diet) for ground corn to achieve the additional dietary treatments. The level of supplemental Mg chosen for this experiment was based on a small pilot study (data not shown) using three levels (1, 2, or 4%) of $KMgSO_4$. Feeding 2% $KMgSO_4$ elicited a 10% increase in serum Mg without reducing ADFI. Analysis of the $KMgSO_4$ indicated that it contained 17.9% K, 12.8% Mg, and 24.1% S.

Pigs were housed in an environmentally controlled finishing barn with two pigs in each 4 ft × 4 ft totally slatted-floored pen. Pigs were allowed ad libitum access to feed and water through one single-hole self-feeder and a nipple waterer, respectively. Pigs were weighed every 14 d in order to determine ADG, ADFI, and F/G. Pigs also were weighed at the beginning and end of the Mg supplementation period. Serum samples were obtained from each pig at the beginning of the Mg supplementation period and again 5 days later for the determination of initial and final Mg levels, respectively. Blood samples also were obtained on the fifth day of Mg supplementation for the determination of whole blood metabolic profiles. Feed was not withheld from pigs prior to blood sampling. Whole blood profiles were determined within 20 minutes of sampling, and serum Mg samples were stored frozen until analyzed.

One pig (closest to the average of all pigs) per pen was slaughtered after 7 days of receiving supplemental Mg (average weight of pigs at slaughter was 260 lb). Thirty minutes after exsanguation, a 1-inch core of the longissimus muscle, which corresponded to the last rib, was removed from each pig, dipped in liquid nitrogen, placed on dry ice, and ultimately stored at -70°C until analyzed for glycogen and lactic acid content. Standard carcass measurements; visual analyses of the longissimus for coloring, marbling, and firmness; drip loss; and Minolta color spectrometry (L*, a*, and b*) were obtained for each pig 24 h postmortem (drip loss = 48 h postmortem).

Data were analyzed as a randomized complete block. Pen was the experimental unit for the growth performance data and individual pig for the carcass characteristics. The GLM procedure of SAS was used for the single degree of freedom contrast between the two dietary treatments during the growth trial. All subsequent data were analyzed as a 2 × 2 factorial arrangement with main effects of MTO (0 or .50% of the diet) or supplemental Mg (0 or 7.75 g of elemental Mg/d for 7 days preslaughter). The statistical model included main effects and interactions of the main effects. Hot carcass weight was used as a covariate in the statistical model for carcass analysis.

Results and Discussion

Growth Performance. Modified tall oil did not affect (P>.15) ADG, ADFI, or F/G during the growth trial, and the addition of Mg also did not affect (P>.10) these parameters. Thus, growth performance data are presented in Table 2 in a combined format.

Carcass Characteristics and Meat Quality. Feeding MTO reduced (P<.05) first and tenth rib backfat and average backfat (Table 3). Feeding supplemental Mg also reduced (P=.05) first rib backfat and resulted in an interaction (P=.03) with MTO for last lumbar backfat; Mg reduced it in diets containing MTO but increased it in diets not containing MTO. Interactions of MTO and Mg were also observed for lean percentage (P=.10) and dressing percentage (P=.05). Both were increased by Mg in diets containing MTO but reduced in diets not containing MTO. Feeding MTO increased (P=.04) intramuscular marbling, and supplemental Mg decreased (P=.04) longissimus glycogen content. Magnesium supplementation increased (P=.0001) serum Mg levels by about 7% over those of pigs fed diets without supplemental Mg. Other carcass characteristics and meat quality measures were not affected (P>.10) by dietary treatment.

Blood Gas and Metabolic Profiles. Feeding MTO increased (P=.05) glucose levels in the whole blood (Table 4). Magnesium supplementation decreased (P<.10) pH,

BUN, and base excess and increased (P<.10) K^+, ionized Mg^{++}, and lactate.

The results of this trial indicate that MTO and(or) Mg did not influence growth performance but did reduce backfat. Additionally, MTO may positively influence some measures of meat quality, such as increasing intramuscular marbling. These responses to dietary supplementation with MTO are in general agreement with prior work. Among six other reports, three noted improvements in growth performance (combinations of ADG, ADFI, and F/G) from MTO, and none reported decreases in performance. In addition, MTO also reduced backfat in three of those studies. We should note that the improvements in growth performance from feeding MTO were not necessarily coupled with the decreases in backfat. Thus, feeding MTO may improve growth performance, reduce backfat, or both. Feeding MTO increased belly firmness in all four studies in which that measurement was taken, regardless of level or source of supplemental fat present in the diets. Although improvements in color, drip loss percentage, and pH were not observed in this study, supplementing diets fed to swine with Mg may be beneficial to the overall quality of the final retail product. The postmortem reduction in longissimus glycogen content by Mg should reduce the amount of lactate produced in the muscle, thereby maintaining a higher pH and reducing drip loss percentage while maintaining color stability. More research needs to be conducted with both feed additives to determine their full value in improving overall meat quality.

Table 1. Composition of Basal Diets (As-Fed Basis)

Ingredient, %	Growing[a]	Finishing[b]	7-d Preslaughter[c]
Corn	69.24	78.58	76.58
Soybean meal (46.5% CP)	27.47	18.39	18.39
Limestone	1.06	.89	.89
Monocalcium phosphate	.85	.76	.76
Soybean oil[d]	.50	.50	.50
Salt	.35	.35	.35
Vitamin premix	.25	.25	.25
Trace mineral premix	.15	.15	.15
Antibiotic[e]	.13	.13	.13
$KMgSO_4$[f]	----	----	2.00
Total	100.00	100.00	100.00

[a]Growing diets were fed from 101 to 101 lb BW and were formulated to contain 1.00% lysine, .65% Ca, and .55% total P.
[b]Finishing diets were fed from 101 to 252 lb BW and were formulated to contain .75% lysine, .55% Ca, and .50% total P.
[c]Diets were fed for 7 days prior to slaughter (252 to 260 lb BW) and were formulated to contain .75% lysine, .55% Ca, and .50% total P.
[d]Soybean oil was substituted on an equal weight basis for MTO to give the experimental treatments.
[e]Provided 100 g/ton tylosin.
[f]$KMgSO_4$ was substituted on an equal weight basis (2% of total diet) for corn during the last 7 days of the finishing period to achieve the additional dietary treatments.

Table 2. Growth Performance of Gilts Fed MTO[a]

	MTO, %			Contrast Probability
Item	0	.50	CV	(*P* =)
101 to 260 lb BW				
ADG, lb	2.20	2.14	5.62	.24
ADFI, lb	6.26	6.08	6.30	.16
F/G	2.86	2.86	4.87	.63

[a]Values are means for two pigs per pen and 20 replicate pens per treatment.

Table 3. Carcass Characteristics of Gilts Fed MTO, $KMgSO_4$, or Both[a,b]

	0 MTO/mg		.50% MTO/mg			Probability Values (*P* =)		
Item	0	7.75g/d	0	7.75 g/d	CV	MTO×Mg	MTO	Mg
Shrink loss, %	1.30	1.16	.91	1.10	76.08	.58	.45	.94
Backfat, in								
First rib	1.54	1.50	1.46	1.35	7.89	.34	.004	.05
Tenth rib	.74	.85	.70	.67	18.00	.12	.02	.34
Last rib	.85	.86	.82	.79	13.72	.60	.18	.77
Last lumbar	.67	.75	.73	.64	16.91	.03	.52	.91
Average[c]	1.02	1.04	1.00	.92	10.00	.15	.05	.35
LMA, in^2	6.73	6.65	6.69	7.22	10.04	.20	.17	.29
Lean %[d]	54.03	52.90	54.53	55.84	4.19	.10	.02	.90
Dressing %	74.99	74.76	73.71	75.49	2.00	.05	.66	.10
Visual color[e]	2.60	2.55	2.55	2.70	21.27	.55	.82	.78
Firmness[e]	2.55	2.55	2.80	2.75	26.24	.92	.33	.91
Marbling[e]	1.95	2.25	2.45	2.45	22.04	.37	.04	.36
L*[f]	53.73	53.50	53.59	54.77	6.12	.53	.54	.64
a*[f]	12.71	14.53	12.99	12.68	18.60	.19	.31	.34
b*[f]	8.59	9.76	8.55	8.61	24.07	.41	.41	.37
Hue angle[f]	33.98	33.50	33.08	34.02	7.65	.42	.91	.76
Saturation index[f]	15.35	17.53	15.57	15.34	19.92	.24	.33	.34
a*/b*[f]	1.49	1.53	1.55	1.49	9.97	.33	.96	.78
Drip loss, %	5.64	6.20	5.79	6.34	36.36	.99	.84	.44
Carcass length, in	32.50	32.68	32.68	32.93	2.63	.95	.37	.42
Muscle metabolites								
Glycogen, mg/g	4.77	4.13	4.85	3.75	29.61	.55	.69	.04
Lactic acid, mg/g	4.12	4.00	3.90	3.74	21.69	.94	.38	.59
Serum Mg, mg/L[g]								
Initial	20.59	20.47	20.37	20.84	4.15	.28	.79	.53
Final	21.27	22.37	20.85	22.91	3.85	.53	.36	.0001

[a]Values represent one pig per pen and 10 replicate pens per treatment.
[b]Hot carcass weight was used as a covariate in the statistical analysis.
[c]Average backfat is the average of the first and last rib and last lumbar fat depths.
[d]Lean percentage was derived from NPPC (1991) equations with 5% fat in the carcass.
[e]Scoring system of 1 to 5: 2 = grayish pink, traces to slight, or soft and watery; 3 = reddish pink, small to modest, or slightly firm and moist; and 4 = purplish red, moderate to slightly abundant, or firm and moderately dry for color, firmness, and marbling, respectively.
[f]Means were derived from three sample readings per loin. Measures of dark to light (L*), redness (a*), yellowness (b*), red to orange (hue angle), or vividness or intensity (saturation index).
[g]Values are means of two pigs per pen and 10 replicate pens per treatment.

Table 4. Whole Blood Profiles of Gilts Fed MTO, $KMgSO_4$, or Both[a]

	0 MTO/mg		.50% MTO/mg			Probability Values (P =)		
Item	0	7.75 g/d	0	7.75 g/d	CV	MTO×Mg	MTO	Mg
pH	7.395	7.383	7.398	7.368	.40	.36	.55	.04
PCO_2, mmHg	56.5	57.7	55.5	58.8	8.20	.50	.97	.14
PO_2, mmHg	44.5	49.3	47.0	42.8	23.25	.20	.57	.92
Oxygen saturation, %	75.6	76.1	75.6	70.9	9.60	.27	.27	.39
Hematocrit, %	41	41	41	41	6.41	.83	.70	.55
Hemoglobin, g/dL	13.6	13.4	13.7	13.5	6.34	.78	.76	.48
Na^+, mmol/L	146	147	147	147	.79	.63	.38	.18
K^+, mmol/L	5.0	5.1	4.9	5.1	5.91	.73	.63	.10
Cl^-, mmol/L	102	103	103	103	.79	.69	.35	.98
Ionized Ca^{++}, mg/dL	5.34	5.36	5.32	5.42	2.68	.37	.65	.20
Ionized Mg^{++}, mg/dL	.88	.98	.92	.97	12.85	.51	.81	.07
Glucose, mg/dL	97	92	98	98	5.58	.20	.05	.16
Lactate, mmol/L	2.5	2.9	2.7	3.9	44.30	.30	.19	.08
BUN, mg/dL	14	11	14	11	19.88	.99	.95	.01
Osmolarity, mOsm/kg	291	291	292	292	.96	.87	.37	.96
Anion gap, mmol/L	14.4	15.0	14.7	16.0	6.68	.37	.05	.008
HCO_3^-, mmol/L	34.7	34.4	34.2	33.7	3.30	.74	.13	.31
Oxygen content, mL/dL	15.1	15.2	15.1	14.2	9.72	.28	.29	.41
Total CO_2, mmol/L	36.4	36.2	35.9	35.6	3.33	.83	.15	.49
Alveolar oxygen, mmHg	76.3	74.7	77.4	73.5	7.38	.51	.98	.14
Base excess-WB, mmol/L[b]	8.4	8.0	8.2	7.1	13.99	.41	.11	.04
Base excess-ECF, mmol/L[c]	9.6	9.2	9.2	8.3	13.34	.51	.10	.08

[a]Values represent one pig per pen and 10 replicate pens per treatment.

[b]Base excess in the whole blood.

[c]Base excess in the extracellular fluid.

INFLUENCE OF DIETARY SUPPLEMENTATION OF MODIFIED TALL OIL, CHROMIUM NICOTINATE, AND L-CARNITINE ON PORK CHOP DISPLAY COLOR STABILITY, WARNER-BRATZLER SHEAR, AND SENSORY PANEL TRAITS[1]

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Summary

Eighty crossbred (PIC) gilts were used to determine the influence of feeding modified tall oil (MTO, 0 or .5% of diet), chromium nicotinate (0 or 50 ppb), and L-carnitine (0 or 50 ppm) on display color stability, Warner-Bratzler shear, and sensory panel traits of pork chops. Dietary additions of MTO, chromium nicotinate, and L-carnitine to growing and finishing swine diets had minimal effects on quality characteristics and display color stability of pork chops. Therefore, producers probably can take advantage of any production or carcass cutability improvement from these feed supplements without affecting muscle quality of pork chops.

(Key Words: Modified Tall Oil, Chromium Nicotinate, L-Carnitine, Pork Chop.)

Introduction

Modified tall oil is a by-product of the pulp and paper industry and has a high content of conjugated linoleic acid (67.4%). Supplementation of swine diets with MTO has decreased backfat, increased lean percentage, and increased belly firmness. Chromium (Cr) is an essential trace element involved in metabolism. Swine diet supplementation of Cr has decreased backfat and increased loin eye area in pork carcasses. Carnitine is a naturally occurring B-vitamin-like compound involved in normal metabolism. Feeding pigs carnitine has resulted in larger loin eye areas and a greater percentage of muscle on pork carcasses.

Limited information is available on the influence of feeding dietary combinations of MTO, Cr nicotinate, and L-carnitine on pork chop quality. Therefore, this experiment was conducted to determine that influence.

Procedures

In a 2 × 2 × 2 factorial arrangement, 80 crossbred (PIC) gilts were blocked by initial BW (100 lb) and ancestry and randomly allotted to one of eight dietary treatments. Two pigs were fed in each pen with five replicate pens per treatment. The main effects were two levels of MTO (0 or .5% of the diet), two levels of Cr nicotinate (0 or 50 ppb), and two levels of L-carnitine (0 or 50 ppm). The basal growing diet was fed from 100 lb to 160 lb BW and consisted of 66.5% corn and 27.7% soybean meal formulated to contain 1.0% lysine. The basal finishing diet was fed from 160 lb to 235 lb BW and consisted of 76.9% corn and 18.5% soybean meal formulated to contain .75% lysine.

Pigs were harvested humanely using standard industry procedures approved by the Kansas State University Animal Care Committee. At 28 h postmortem, the right side of each carcass was fabricated into the wholesale cuts of ham, loin, belly, spareribs, and shoulder. From the wholesale loin, a 9-in. long boneless loin sample was removed from the tenth rib and posterior. The loin was

[1]Appreciation is expressed to Lonza Inc., Fair Lawn, NJ for assistance in this research project.
[2]Northeast Area Extension Office, Manhattan, KS.
[3]Lonza Inc., Fair Lawn, NJ.

vacuum packaged and aged for an additional 6 d at 34°F. At 7 d postmortem, each loin was faced at the tenth rib surface and cut into 1-in. chops. Cutting anterior to posterior, chops were assigned as follows: 1) display color, 2) 0 d thiobarbituric acid reacting substance (TBARS), 3) 5 d TBARS, 4) sensory panel, and 5) Warner-Bratzler shear force (WBS). Display color and 5 d TBARS chops were placed immediately in retail display cases. Chops for sensory panel, 0 d TBARS, and WBS were crust frozen for 30 min at -40°F, individually vacuum packaged, and stored at -40°F until analysis.

Display chops were packaged in PVC film and displayed at 36°F under continuous lighting of 1614 lux from Philips Deluxe Warm White (40 watt) fluorescent lights. Visual display color was evaluated to the nearest .5 by eight display color panelists. The 5-point color scale used consisted of 1 = bright grayish-pink or reddish-pink, 2 = grayish-pink or reddish-pink, 3 = slightly dark pink/red to brown, 4 = moderately dark pink/red to brown, and 5 = dark pink/red to brown. A score of 3.5 indicated when the product had sufficient visual color deterioration to be discounted or unsaleable. Spectral data for ratio of reflectance %R630 nm /%R580 nm and CIE L*a*b* values were measured using a Hunter LabScan Spectrocolorimeter (Illuminant C). Three surface readings per sample were taken and averaged. Color was evaluated on 0, 1, 3, 5, and 7 d of display.

The extent of lipid oxidation was measured as TBARS at 0 and 5 d of display. The 0-d TBARS chops were cut, immediately packaged, crust frozen at -40°F for 30 min, vacuum packaged, and stored at -40°F. The 5-d TBARS chops were displayed in the cases for 5 d as previously described and then frozen and stored at -40°F. Values for duplicate samples from each chop were averaged and expressed as mg malonaldehyde/kg dry matter.

The chops were weighed and cooked to an internal temperature of 160°F in a Blodgett dual-air-flow oven. Chops were cooled at room temperature (70°F) for 1 h, reweighed, and subsequently chilled for 24 h at 36°F before six .5-in.-diameter cores were removed parallel to the muscle fibers and sheared perpendicular to the muscle fibers using a WBS attachment on an Instron Universal Testing Machine. Percentages of thawing and cooking losses were calculated.

The chops for sensory evaluation were thawed and cooked to an internal temperature of 160°F. Chops were removed from the oven and immediately cut into cubes of .5 in. × .5 in. × cooked chop thickness. A trained seven-member descriptive attribute sensory analysis panel received two warm samples from each chop. Six sensory traits of myofibrillar tenderness, connective tissue amount, overall tenderness, juiciness, flavor intensity, and off-flavor were evaluated on an 8-point scale to nearest .5. Myofibrillar tenderness and overall tenderness were evaluated on a scale from 1 = extremely tough to 8 = extremely tender. Connective tissue was ranked on a scale from 1 = abundant to 8 = none. Juiciness was scored on a scale from 1 = extremely dry to 8 = extremely juicy. Flavor intensity was evaluated on a scale from 1 = extremely bland to 8 = extremely intense. Off-flavor intensity was ranked from 1 = extremely intense to 8 = none.

The experimental design was a 2 × 2 × 2 factorial in a randomized complete block design using initial weight and ancestry to establish blocks. Statistical analyses were performed with the GLM procedure of SAS using the pen mean as the experimental unit. For comparisons pertaining to measurements over time, a split-plot analysis using the Mixed procedure of SAS was conducted to account for repeated measurements that included the fixed effects of treatment and display days. All main effect and interaction means were separated ($P<.05$) using the Least Significant Difference procedure when the respective F-tests were significant ($P<.05$).

Results and Discussion

Visual color panel and instrumental display data of pork chops are presented as MTO, Cr, and L-carnitine main effect means

in Table 1. Panel scores for visual display color were similar (P>.10) for all treatments. As expected, display time influenced (P<.001) visual scores, as well as CIE L*a*b*, and ratio of reflectance values (Table 2). Visual color scores dramatically declined over the 7 d of display. Scores were consistently lower (P<.05) at each evaluation period.

No treatment differences (P>.10) were observed for display CIE L*, CIE a*, or ratio of reflectance values (Table 1). Chops at 0, 1, and 3 d of display had lower (P<.05) L* values (darker color) than chops at 5 and 7 d of display (Table 2). In addition, chops at 5 d of display had lower (P<.05) CIE L* values than chops at 7 d of display. The highest (P<.05) a* value was observed at 1 d of display, and values decreased (P<.05) at 1 and 3 d of display. The lowest a* values were detected (P<.05) at 5 and 7 d of display. Chops from pigs fed MTO had higher (P<.05) b* values (an indicator of yellowness) than chops from pigs fed no MTO. Chops had the highest (P<.05) b* values at 0 d of display and the lowest (P<.05) b* values at 7 d of display. In addition, chops at 1 and 3 d of display had higher (P<.05) b* values than chops at 5 d of display. The ratio of reflectance %R630/%R580, which is an indicator of the amount of oxymyoglobin present, was consistently lower (P<.05) at each successive evaluation period during display.

Table 1. Influence of Modified Tall Oil, Chromium Nicotinate, and L-Carnitine Supplementation on Display Visual Color, Instrumental Color, and TBARS[a] Values of Pork Loin Chops

	Treatment						
	Modified Tall Oil, %		Chromium Nicotinate, ppb		L-Carnitine, ppm		
Item	0	.5	0	50	0	50	SE
Visual Color[b]	3.03	3.02	2.99	3.06	3.06	2.99	.12
Instrumental Color[c]							
L*	56.52	57.57	56.51	57.58	57.02	57.07	.58
a*	6.18	6.003	6.25	5.96	6.03	6.18	.20
b*	20.21[d]	20.55[e]	20.51	20.24	20.46	20.30	.17
%R630/%R580	2.05	2.08	2.09	2.04	2.05	2.08	.05
TBARS[a]	.74	.59	.69	.64	.63	.70	.08

[a]Thiobarbituric acid reacting substance, mg malonaldehyde/kg dry matter.
[b]Scores 1 to 5: 3 = slightly dark pink/red to brown.
[c]Measure of lightness (L*), redness (a*), yellowness (b*), or indicator of the amount of oxymyoglobin present (ratio of reflectance %R630/%R580).
[d,e]Means within modified tall oil and the same row with a different superscript differ (P<.05).

Thiobarbituric acid reacting substance values were not affected (P>.10) by dietary treatment (Table 1). As expected, the day of display influenced (P<.001) TBARS values (Table 2). The TBARS measurements of chops at 0 d were lower (P<.05) than those of chops displayed for 5 d.

The WBS and sensory panel main effect means for chops are presented in Table 3. The connective tissue amount, juiciness, flavor intensity, and off-flavor attributes were similar (P>.05) among treatments (Table 3). Myofibrillar and overall tenderness scores for chops from pigs fed no MTO

were higher (P<.05; less tough) than the sensory scores from pigs fed MTO. However, this difference was not supported by WBS values.

Previous research has indicated that CLA, Cr, and L-carnitine can improve feed efficiency and the proportion of lean to fat in swine. However, dietary additions of MTO, Cr, and L-carnitine to swine diets had minimal effect on display color and quality characteristics of pork chops. Therefore, producers probably can take advantage of any production or carcass cutability improvement from these feed supplements without effect on loin chop quality.

Table 2. Influence of Day of Display on Visual Color, Instrumental Color, and TBARS[c] Measurements of Pork Loin Chops

	Day					
Item	0	1	3	5	7	SE
Visual Color[a]	1.97[d]	2.51[e]	3.00[f]	3.57[g]	4.10[h]	.11
Instrumental Color[b]						
L*	56.28[d]	56.52[d]	56.68[d]	57.60[e]	58.14[f]	.45
a*	7.07[f]	7.62[g]	6.12[e]	5.01[d]	4.70[d]	.28
b*	21.34[g]	20.96[f]	20.61[f]	19.89[e]	19.09[d]	.19
%R630/%R580	2.56[h]	2.34[g]	2.06[f]	1.80[e]	1.55[d]	.05
TBARSc	.48[d]	--	--	.85[e]	--	.08

[a]Scores 1 to 5: 2 = grayish-pink or reddish-pink; 3 = slightly dark pink/red to brown; 4 = moderately dark/pink red to brown.
[b]Measure of lightness (L*), redness (a*), yellowness (b*), or indicator of the amount of oxymyoglobin present (ratio of reflectance %R630/%R580).
[c]Thiobarbituric acid reacting substance, mg malonaldehyde/kg dry matter.
[d,e,f,g,h]Means in the same row with a different superscript letter differ (P<.05).

Table 3. Influence of Modified Tall Oil, Chromium Nicotinate, and L-carnitine Supplementation on Warner-Bratzler Shear and Sensory Panel Traits

	Treatment						
	Modified Tall Oil, %		Chromium Nicotinate, ppb		L-Carnitine, ppm		
Item	0	.5	0	50	0	50	SE
Thawing loss, %	1.66	1.78	1.85	1.59	1.78	1.66	.24
Cooking loss, %	27.97	27.10	27.63	27.44	27.43	27.64	.60
Shear force, kg	3.05	3.14	3.00	3.18	2.98	3.20	.13
Sensory Evaluation[a]							
Myofibrillar tenderness	6.18[c]	5.86[b]	6.06	5.99	6.08	5.96	.10
Connective tissue	7.21	7.07	7.19	7.09	7.16	7.11	.06
Overall tenderness	6.25[c]	5.92[b]	6.14	6.04	6.16	6.01	.10
Juiciness	5.38	5.30	5.41	5.27	5.30	5.38	.07
Flavor intensity	5.69	5.62	5.70	5.61	5.65	5.66	.05
Off-flavor	7.92	7.86	7.88	7.91	7.89	7.90	.30

[a]Scores of 1 to 8: myofibrillar tenderness (5 = slightly tender and 6 = moderately tender); connective tissue (6 = traces and 7 = practically none); overall tenderness (5 = slightly tender and 6 = moderately tender); juiciness (4 = slightly dry and 5 = slightly juicy); off flavor (7 = practically none and 8 = none).
[b,c]Means within modified tall oil and the same row with a different superscript letter differ (P<.05).

INFLUENCE OF DIETARY SUPPLEMENTATION OF MODIFIED TALL OIL, CHROMIUM NICOTINATE, AND L-CARNITINE ON BACON CHARACTERISTICS[1]

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Summary

Eighty crossbred (PIC) gilts were used to determine the influence of feeding modified tall oil (MTO, 0 or .5% of diet), chromium nicotinate (0 or 50 ppb), and L-carnitine (0 or 50 ppm) on bacon quality characteristics. Supplementation of MTO improved bacon slice firmness. Dietary additions of MTO, chromium nicotinate, and L-carnitine to diets for growing and finishing swine had minimal effects on other bacon characteristics. Therefore, producers probably can take advantage of any improvements in production or carcass cutability from these feed supplements without affecting bacon quality.

(Key Words: Bacon, Modified Tall Oil, Chromium Nicotinate, L-Carnitine.)

Introduction

Modified tall oil is a by-product of the pulp and paper industry and has a high content of conjugated linoleic acid (67.4%). Supplementation of swine diets with MTO has decreased backfat, increased lean percentage, and increased belly firmness. Chromium (Cr) is an essential trace element involved in metabolism. Swine diet supplementation with Cr has decreased backfat and increased loin eye area in pork carcasses. Carnitine is a naturally occurring B-vitamin-like compound involved in normal metabolism. Feeding pigs carnitine has resulted in larger loin eye areas and a greater percentage of muscle on pork carcasses.

Investigations into the effects of chromium, carnitine, and MTO on bacon production and quality characteristics have not been conducted. Therefore, the objective of this study was to determine those effects.

Procedures

In a 2 × 2 × 2 factorial arrangement, 80 crossbred (PIC, Franklin, KY; L 326 or L 327 × C 22) gilts were blocked by initial BW (100 lb) and ancestry and randomly allotted to one of eight dietary treatments. Two pigs were fed in each pen with five replicate pens per treatment. The main effects were two levels of MTO (0 or .5% of the diet), two levels of chromium nicotinate (Cr; 0 or 50 ppb), and two levels of L-carnitine (0 or 50 ppm). The basal growing diet was fed from 100 lb to 160 lb BW and consisted of 66.5% corn and 27.7% soybean meal formulated to contain 1.0% lysine. The basal finishing diet was fed from 160 lb to 235 lb BW and consisted of 76.9% corn and 18.5% soybean meal formulated to contain .75% lysine.

Pigs were harvested humanely using standard industry procedures approved by the Kansas State University Animal Care Committee. At 28 h postmortem, the right side of each carcass was fabricated into the wholesale cuts of ham, loin, belly, spareribs, and shoulder. Bellies were weighed, vacuum packaged, and stored at -40°F until utilized for bacon manufacture, when they were thawed at 37°F for 72 h in their vacuum bags. The bellies were weighed and injected

[1]Appreciation is expressed to Lonza Inc., Fair Lawn, NJ for assistance in this research project.
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with pickle (10% of the weight) using a multineedle pump injector and reweighed. The pickle was a standard curing mixture (13.2 % salt, 7% sugar, 1.0% sodium nitrite, 2% maple sugar, and 76.8% water). Bellies were tumbled for 4 h, weighed, and hung on bacon combs before cooking in a smokehouse. After attaining an average internal temperature of 147°F (approximately 2 h), bellies were weighed, skin was peeled, and bellies were reweighed and rehung. The bellies were placed back in the smokehouse, smoked with 100% hickory wood sawdust, and processed to an internal temperature of 135°F. Bellies were removed from the smokehouse and placed in a 37°F cooler for 40 h and reweighed. Percentages of belly thawing loss, pumping uptake, tumbling loss, cooking loss, and final yield were calculated.

Cured bellies were cut into .16-in. bacon slices. Twelve slices at approximately one-third the length of the bacon slab from the cranial end were obtained for analysis. Slices were evaluated for firmness, number of holes, and thickness of belly. Firmness was evaluated on a scale of 1 = very soft oily to 8 = very brittle and crumbly. A score of 5 was optimal. Composite subjective evaluation of number and size of holes used a scale of 1 = very high number and 8 = none. The depth of the sixth bacon slice removed was measured to determine cured belly thickness. Eight slices were vacuum packaged, stored at 37°F for 4 d, and used for sensory evaluation.

Bacon slices were removed from their vacuum bag and cooked for 5 min on each side in a Blodgett dual-air-flow oven set at 350°F. Cooked bacon slices were cut into 1 in. × 1 in. subsamples (pieces). A trained 12-member qualitative descriptive analysis panel evaluated two subsamples. Eight samples (one from each treatment) per session were evaluated warm. Five sensory traits of brittleness, flavor intensity, saltiness, aftertaste, and off-flavor were evaluated on 8-point scales. Brittleness was evaluated on a scale from 1 = soft to 8 = extremely crispy. Flavor intensity was ranked on a scale from 1 = extremely bland to 8 = extremely intense. Saltiness was scored on a scale from 1 = extremely unsalty to 8 = extremely salty. Aftertaste was scored on a scale from 1 = none to 8 = extremely intense. Off-flavor intensity was ranked from 1 = extremely intense to 8 = none.

The experimental design was a 2 × 2 × 2 factorial experiment in a randomized complete block design using initial weight and ancestry to establish blocks. Statistical analyses for bacon measurements were performed with the GLM procedure of SAS using the pen mean as the experimental unit. All main effect and interaction means were separated ($P<.05$) using the Least Significant Difference procedure when the respective F-tests were significant ($P<.05$).

Results and Discussion

Bacon production, quality, and sensory traits are reported in Table 1. Bacon slices from pigs fed MTO were firmer ($P<.001$) than slices from pigs not fed MTO. The differences in slice firmness can be attributed partially to firmer bellies found in pigs fed MTO. All other bacon production and quality characteristics were similar ($P>.10$) among treatments.

Panelists' sensory evaluations of bacon for brittleness, flavor intensity, and saltiness were similar ($P>.05$) among all treatments. Pigs fed Cr produced bacon that had more ($P<.05$) aftertaste than pigs receiving no Cr. A Cr × L-carnitine interaction was observed ($P = .03$) for the off-flavor attribute. Bacon from pigs fed Cr and L-carnitine (7.73) had higher ($P<.05$) off-flavor scores (less total off-flavor) than bacon from pigs fed Cr but no L-carnitine (7.54). The no Cr with L-carnitine (7.59) and no Cr with no L-carnitine (7.69) treatment combinations were intermediate.

Previous research has indicated that MTO, Cr, and L-carnitine can improve feed efficiency and the proportion of lean to fat in swine. The additions of MTO, Cr, and L-carnitine to swine diets had minimal effects on bacon processing and sensory traits.

Therefore, producers probably can take advantage of any improvements in production or carcass cutability from these feed supplements without affecting bacon quality.

Table 1. Influence of Modified Tall Oil, Chromium Nicotinate, and L-Carnitine Supplementation on Production, Quality, and Sensory Traits of Bacon

	Modified Tall Oil, %		Chromium Nicotinate, ppb		L-Carnitine, ppm		
Item	0	.5	0	50	0	50	SE
Production Evaluations							
Thawing loss, %	1.18	1.21	1.25	1.14	1.20	1.19	.16
Pumping, %	8.65	8.26	8.39	8.52	8.54	8.37	.25
Pumping loss, %	.80	.58	.60	.78	.69	.69	.14
Cooking loss, %	27.54	27.91	27.88	27.58	27.98	27.48	.49
Final yield, %	77.99	77.41	77.46	77.95	77.54	77.87	.55
Quality Evaluations[a]							
Thickness, in	1.05	1.08	1.05	1.08	1.04	1.09	.03
Slice firmness	2.79[d]	3.91[e]	3.41	3.29	3.39	3.31	.15
Slice holes	5.64	5.68	5.71	5.60	5.73	5.59	.16
Sensory Analysis[b]							
Brittleness	4.73	4.70	4.70	4.72	4.73	4.70	.08
Flavor intensity	4.87	4.77	4.81	4.83	4.85	4.79	.05
Saltiness	4.46	4.42	4.44	4.44	4.46	4.43	.05
Aftertaste	4.18	4.14	4.10f	4.21g	4.17	4.15	.04
Off-flavor[c]	7.66	7.62	7.64	7.64	7.62	7.66	.05

[a]Thickness of cured belly at one-third the length of the bacon slab from the cranial end; scores of 1 to 8 for slice firmness and holes: 1 = very soft oily, 8 = very brittle and crumbly; and 1 = high number of holes, 8 = no holes, respectively.

[b]Scores of 1 to 8: brittleness (4 = slightly soft and 5 = slightly crisp); flavor intensity (4 = slightly bland and 5 = slightly intense); saltiness (4 = slightly unsalty and 5 = slightly salty); aftertaste (4 = slight and 5 = slightly intense); off flavor (7 = practically none and 8 = none).

[c]Chromium × L-carnitine interaction.

[d,e]Means within modified tall oil and the same row with a different superscript differ (P<.05).

[f,g]Means within chromium and the same row with a different superscript differ (P<.05).

INTERACTIVE EFFECTS OF MODIFIED TALL OIL AND FAT SOURCE ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF FINISHING BARROWS AND GILTS

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Summary

A total of 144 pigs (initially 90 lb) was used to determine the interactive effects of fat source: none (NF), 6% choice white grease (CWG), or 6% poultry fat (PF); modified tall oil (MTO, 0 or .5%); and sex (barrows or gilts) on growth performance and carcass characteristics. Regardless of fat source, MTO improved belly firmness but did not influence growth performance. Gilts were leaner, had increased loin muscle area, and had softer bellies compared to barrows. Added fat decreased ADFI and improved F/G. Pigs fed PF had the best F/G, but the fattest carcasses and softest loins and bellies.

(Key Words: Finishing Pigs, Fat, Modified Tall Oil.)

Introduction

Adding animal fat to increase the energy concentration of diets is a common practice in the swine industry. Previous research conducted at Kansas State University showed that when pigs were fed diets containing 2 to 6% CWG or PF, F/G improved without affecting loin muscle area, tenth rib backfat, or lean percentage, with no differences observed between fat sources. However, the study showed that adding CWG had no adverse affects on carcass quality, but PF tended to increase loin cooking loss and was associated with a greater incidence of "off flavors" in bacon sensory evaluations. Research in other laboratories has shown that pigs fed diets containing unsaturated animal fats, such as PF, may have less desirable carcass characteristics (softer and more unsaturated fat) compared to pigs fed diets containing CWG.

Recent research conducted at Kansas State University has shown that feeding diets containing .5% MTO improved growth performance as well as decreased backfat and improved lean percent, longissimus drip loss, and belly firmness. Consequently, we hypothesized that perhaps the detrimental effects on pork quality exhibited by pigs fed unsaturated animal fats could be alleviated by the addition of MTO. Therefore, the objective of this research was to determine the interactive effects of sex, MTO, and fat source on growth performance and carcass characteristics of finishing pigs.

Procedures

A total of 144 pigs (initially 90 lb) was allotted by sex, ancestry, and weight to one of 12 treatments. Experimental treatments had six replications (pens) and two pigs per pen.

The 12 treatments were arranged in a 2×2×3 factorial with main effects of sex (barrows or gilts); MTO (0 or .5%); or fat source (none, 6% CWG, or 6% PF). Dietary treatments (Table 1) were fed in meal form in two phases (90 to 146 and 146 to 250 lb). Modified tall oil replaced corn starch in the basal diet on an equal weight basis. Diets were formulated on an equal lysine:calorie ratio basis.

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

Pigs were housed in an environmentally controlled building in 5×5 ft pens. Each pen contained one nipple waterer and one self-feeder to provide ad libitum access to feed and water. Pigs were weighed every 14 d to determine ADG, ADFI, and F/G.

One pig per pen was slaughtered when the average weight of pigs within a block reached 250 lb. Organs (heart, kidneys, liver, and leaf fat) were weighed on the day of slaughter. Standard carcass measurements; visual analyses of the longissimus for color, marbling, and firmness; drip loss; belly firmness; and Minolta colorspectrometry (Hunter L*, a*, and b*) of the longissimus muscle and surrounding fat were determined for each pig at 24 hr postmortem.

Data were analyzed as a 2×2×3 factorial arrangement with pen as the experimental unit using the GLM procedure of SAS. The model contained main effects of sex, MTO, and fat source as well as all possible two- and three-way interactions. Hot carcass weight was used as a covariate for all carcass analysis. Belly length and weight also were used as covariates for the belly firmness analysis.

Results and Discussion

The only main effect interaction (Table 2) occurred for F/G from 90 to 146 lbs (sex × fat source interaction, $P<.05$). Feed to gain ratio was better for barrows and gilts fed diets containing added fat than for those fed diets containing no fat. However, the interaction was the result of barrows fed either CWG or PF exhibiting similar F/G, whereas gilts fed PF had better F/G than those fed CWG.

The remaining treatment differences will be reported as main effect differences only. Average daily gain and ADFI were greater ($P<.0001$) for barrows than for gilts. The addition of MTO did not affect ($P>.10$) ADG, ADFI, or F/G. Pigs fed diets with no added fat tended to have lower ($P<.06$) ADG compared to pigs fed diets containing CWG, and pigs fed diets containing PF had intermediate ADGs. Average daily feed intake was greatest ($P<.002$) for pigs fed diets without added fat and lowest for pigs fed diets containing PF ($P<.0001$).

Main effect differences of carcass characteristics are shown in Table 3. Barrows had thicker tenth rib and average backfat measurements; smaller longissimus muscle areas; lower lean percents and longissimus muscle pHs; and firmer bellies initially and after 1 minute compared to gilts ($P<.04$). Barrows also tended to have redder (visual color) loins; shorter carcasses; and firmer bellies after 5 minutes compared to gilts ($P<.10$). Modified tall oil only tended to improve ($P<.08$) belly firmness initially and after 1 and 5 minutes. Pigs fed diets without fat had greater ($P<.007$) longissimus drip loss and lower ($P<.03$) pH and tended to have softer ($P<.07$) longissimus muscles compared to pigs fed diets containing CWG. Pigs fed diets containing CWG had firmer ($P<.008$) longissimus muscles, less ($P<.04$) longissimus drip loss, and greater ($P<.03$) pH and tended to have less ($P<.09$) average backfat, redder (visual color; $P<.06$) longissimus muscles, and firmer ($P<.09$) bellies after 1 minute compared to pigs fed diets containing PF. Pigs fed diets containing PF had greater ($P<.002$) average backfat thickness, shorter ($P<.05$) carcasses, and softer ($P<.005$) bellies initially and after 1 and 5 minutes compared to pigs fed diets without fat.

Objective color characteristics of the longissimus muscle and fat were not influenced ($P>.10$; Table 4) by MTO or fat source. Barrows had redder (a*), more yellow (b*), and more orange (hue angle) and more intensely colored (saturation index) ($P<.02$) longissimus muscles compared to gilts. The fat surrounding the longissimus muscle was lighter (L*), less red (a*), more yellow (b*), and orange (hue angle) and was more intensely colored (saturation index) ($P<.03$) for barrows compared to gilts.

These results are similar to those previous trials conducted at Kansas State University. Pigs fed diets containing added fat were more efficient than pigs fed diets without fat, and pigs fed diets containing PF had the best

F/G. This is because PF has a slightly greater energy value than CWG (3,710 vs. 3,608 kcal/lb M.E.). However, pigs fed diets containing added fat tended to have poorer carcass characteristics (greater backfat thickness and softer bellies) compared to pigs fed diets without fat. Pigs fed the PF diets had the poorest carcass characteristics compared to pigs fed no fat or CWG diets. Modified tall oil did not influence growth and carcass composition to the same degree as it has in past research and only tended to improve belly firmness. Although no interactions were observed, MTO numerically improved belly firmness of pigs fed diets containing CWG or PF to levels similar to those of pigs fed diets containing NF. Further research to determine the interactive effects of sex, MTO, and fat source on the sensory, texture, and firmness characteristics of bellies and longissimus muscles is still ongoing.

In conclusion, regardless of fat source, MTO improved belly firmness, but did not influence growth performance. Gilts were leaner, had increased loin muscle areas, and had softer bellies compared to barrows. Added fat decreased ADFI and improved F/G. Pigs fed PF had the best F/G, but the fattest carcasses and softest loins and bellies.

Table 1. Compositions of Basal Diets (As-Fed Basis)[a]

Ingredient, %	90 to 146 lb	146 to 250 lb
Corn	69.28	82.81
Soybean meal, 46.5%	26.86	14.11
Monocalcium phosphate	1.35	.85
Limestone	1.08	.87
Corn starch[b]	.50	.50
Salt	.35	.35
Lysine-HCl	.15	.15
Vitamin premix	.15	.13
Trace mineral premix	.15	.10
Medication	.125	.125
Ethoxyguinn	.005	.005
Total	100.00	100.00
Calculated Analysis		
Lysine, %	1.10	.75
Methionine, %	.29	.22
Ca, %	.75	.55
P, %	.65	.50
g lys/Mcal ME	3.35	2.26

[a]Diets were formulated to the same g lys/Mcal ME ratio when choice white grease or poultry fat was added by adjusting the corn and soybean meal ratio.

[b]Modified tall oil replaced corn starch in the basal diet on an equal weight basis.

Table 2. Interactive Effects of Modified Tall Oil and Fat Source on Growing Performance of Barrows and Gilts[a]

	Barrows						Gilts						
	0 MTO			.5% MTO			0 MTO			.5% MTO			
Item	NF[b]	CWG	PF	NF	CWG	PF	NF	CWG	PF	NF	CWG	PF	SEM
90 to 250 lb													
ADG[cd]	2.38	2.48	2.29	2.36	2.42	2.39	2.02	2.18	2.20	2.06	2.06	2.09	.064
ADFI[ce]	6.58	6.53	5.63	6.50	6.03	5.80	5.80	5.48	4.94	5.85	5.36	4.94	.151
F/G[f]	2.77	2.63	2.47	2.77	2.49	2.43	2.87	2.52	2.25	2.85	2.61	2.37	.069

[a]Values represent the means of two pigs (initially 90 lb) per pen with six replications per treatment.

[b]Fat source: NF - no added fat; CWG = 6% added choice white grease; and PF = 6% added poultry fat.

[c]Sex effect, $P<.0001$.

[d]NF vs. CWG, $P<.06$.

[e]NF vs. CWG vs. PF, $P<.002$.

[f]Sex × fat source interaction, $P<.05$.

Table 3. Effects of Sex, Modified Tall Oil, and Fat Source on Carcass Characteristics[a]

	Sex		MTO		Fat Source[b]				Probability, *P*<		Fat Source; Contrasts, *P*<[c]		
Item	Barrows	Gilts	0	.5%	NF	CWG	PF	SEM	Sex	MTO	1	2	3
Shrink loss, %	.79	1.00	.89	.90	.93	.77	.99	.105	.10	.94	.28	.14	.70
Backfat, in													
Tenth rib	.91	.77	.86	.81	.81	.82	.89	.049	.02	.39	.88	.28	.23
Average[d]	1.13	1.06	1.10	1.09	1.05	1.09	1.14	.020	.002	.68	.11	.09	.002
LMA, in^2	6.30	6.91	6.49	6.72	6.65	6.74	6.42	.161	.002	.22	.71	.17	.32
Lean %	51.72	54.39	52.55	53.55	53.51	53.53	52.12	.778	.004	.27	.98	.20	.22
Dressing %	75.43	74.92	75.29	75.06	74.91	75.20	75.43	.340	.19	.57	.54	.64	.29
Visual color[e]	2.61	2.34	2.46	2.50	2.39	2.71	2.34	.137	.09	.80	.10	.06	.80
Firmness[e]	2.59	2.43	2.52	2.49	2.45	2.75	2.32	.113	.21	.79	.07	.008	.39
Marbling[e]	2.27	2.12	2.09	2.30	2.16	2.29	2.14	.132	.34	.16	.46	.40	.92
Drip loss, %	6.05	5.86	5.77	6.13	6.78	4.78	6.30	.505	.74	.54	.007	.04	.51
Carcass loss, %	32.59	32.89	32.74	32.73	32.95	32.73	32.54	.136	.06	.98	.26	.33	.05
Muscling	2.50	2.49	2.47	2.52	2.51	2.48	2.49	.049	.89	.43	.67	.84	.83
pH	5.62	5.70	5.66	5.66	5.65	5.68	5.65	.013	.0001	.91	.03	.03	.98
Belly Firmness[f]													
Initial	14.86	12.21	12.61	14.16	15.44	13.62	11.54	.916	.04	.08	.15	.11	.005
1 min	13.58	11.04	11.39	13.24	14.13	12.42	10.39	.860	.03	.06	.15	.09	.004
5 min	12.51	10.42	10.57	12.36	13.28	11.52	9.60	.814	.06	.06	.12	.10	.003

[a]Values represent the means of one pig per pen and 36 or 24 pens per treatment. Hot carcass weight was used a covariate for the statistical analysis.
[b]Fat source: NF = no added fat; CWG = 6% added choice white grease; and PF = 6% added poultry fat.
[c]Contrasts were: 1) NF vs. CWG, 2) CWG vs. PF, and 3) NF vs. PF.
[d]Refers to the average of the first rib, last rib, and last lumbar fat depths.
[e]Scoring systems of 1 to 5: 2 - grayish pink, soft and watery, or traces to slight; 3 = reddish pink, slightly firm and moist, or small to modest.
[f]Refers to the degree of droop (inches) when the bellies were centrally suspended on a bar, skin side up. Larger values indicate firmer bellies. Belly weight and length were used as covariates in this portion of the statistical analysis.

Table 4. Effects of Sex, Modified Tall Oil, and Fat Source on Objective Color Characteristics of Longissimus Muscle and Fat[a]

	Sex		MTO		Fat Source[b]				Probability, *P*<		Fat Source; Contrasts, *P*<[c]		
Item	Barrows	Gilts	0	.5%	NF	CWG	PF	SEM	Sex	MTO	1	2	3
Muscle[d]													
Hunter L*[f]	59.54	57.61	58.91	58.24	59.12	58.33	58.27	1.08	.12	.59	.60	.97	.58
Hunter a*[f]	10.38	8.93	9.64	9.67	9.71	9.35	9.91	.334	.0003	.94	.45	.24	.68
Hunter b*[f]	17.94	14.29	16.18	16.05	16.27	15.69	16.39	.497	.0001	.83	.41	.32	.86
Hue angle[f]	59.96	58.03	59.23	58.76	59.14	59.10	58.74	.729	.02	.58	.97	.73	.71
Saturation index[f]	1.35	1.32	1.34	1.34	1.34	1.33	1.34	.004	.0001	.83	.50	.30	.72
A:B ratio[f]	.58	.63	.60	.61	.60	.60	.61	.017	.02	.63	.96	.69	.67
Fat[e]													
Hunter L*[f]	85.08	81.67	83.71	83.04	83.66	83.72	82.74	.681	.0001	.40	.95	.31	.35
Hunter a*[f]	.81	1.63	1.15	1.28	1.23	1.22	1.31	.167	.0001	.50	.66	.44	.74
Hunter b*[f]	11.41	9.92	10.61	10.71	10.73	10.55	10.70	.202	.0001	.66	.53	.59	.93
Hue angle[f]	55.60	81.10	67.46	69.24	70.62	61.15	73.28	9.65	.03	.87	.49	.37	.85
Saturation index[f]	1.28	1.26	1.27	1.27	1.27	1.27	1.27	.003	.0001	.46	.98	.92	.95
A:B ratio[f]	.07	.16	.11	.12	.12	.11	.13	.016	.0001	.60	.83	.55	.71

[a]Values represent the means of one pig per pen and 36 or 24 pens per treatment. Hot carcass weight was used a covariate for the statistical analysis.
[b]Fat source: NF = no added fat; CWG = 6% added choice white grease; and PF = 6% added poultry fat.
[c]Contrasts were: 1) NF vs. CWG, 2) CWG vs. PF, and 3) NF vs. PF.
[d]Values are the means of two readings of the longissimus muscle taken at the tenth rib.
[e]Values are the means of four readings of the fat surrounding the longissimus muscle.
[f]Measures of dark to light (Hunter L*), redness (Hunter a*), yellowness (Hunter b*), red to orange (hue angle), or vividness or intensity (saturation index).

MARGINS OF SAFETY CAN BE LOWERED FOR SUPPLEMENTAL COPPER, ZINC, IRON, AND MANGANESE IN FINISHING DIETS WITHOUT AFFECTING GROWTH PERFORMANCE

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Summary

Finishing pig diets are commonly supplemented with copper, zinc, iron, and manganese with large margins of safety compared to those suggested by NRC requirements. In this study, pigs were fed a control diet that provided these minerals supplemented at concentrations similar to current KSU recommendations, diets containing 50 and 25% of the recommendation, or a combination of 50% of the recommendations until 145 lb and no added trace minerals from 145 lb until market. The trial used pigs from 100 lb until market weight at 265 lb. No differences in growth performance or carcass characteristics were observed as a result of trace mineral supplementation. These results suggest that the margins of safety for copper, zinc, iron, and manganese can be lowered significantly in swine finishing diets.

Introduction

Supplemental trace minerals typically are added to swine diets with large margins of safety. These are used because minerals are relatively inexpensive compared to other ingredients in the diet, and few research trials have been conducted to define trace mineral requirements for modern swine production. However, the large margins of safety may result in the excretion of excess trace minerals into swine manure. Therefore, our objective was to determine if lower supplemental trace mineral levels (copper, zinc, iron, and manganese) could be fed during the finishing phase without loss of growth performance.

Procedures

A total of 1,100 barrows (PIC C-22× 337) was used in this experiment. Pigs (25 per pen) were housed in 44 pens of a 1,200-head finishing barn equipped with 48 pens. Pens were blocked according to average pig weight on d 28 after arrival and randomly assigned to treatment within block. Average initial weight was 100.6 lb.

The finishing barn was a double curtain sided, deep pit barn. The barn operates on natural ventilation during warm weather and is equipped with automatic ventilation for cold weather. The floor was totally slatted concrete. Pens were equipped with one four-hole self-feeder and one cup waterer. Pen dimensions were 10 ft × 18.5 ft and provided 7.4 sq ft per pig.

Group weights of all the pigs in each pen were obtained every 2 weeks. Diet phase changes occurred at 4-week intervals. Feeders were vacuumed on the day that diet phases were changed, and the remaining amounts of feed recorded. Pigs in all pens were weighed at market before shipping to the processing plant. The pigs in each pen were marked with a different tattoo prior to marketing to allow carcass data to be collected and calculated back to each pen. Standard plant carcass criteria were measured including carcass weight, fat depth, loin depth, lean percentage, and fat free lean index.

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The trial was a randomized complete block design with four treatments per block. (Table 1). All diets were corn-soybean meal based. Diets were formulated in four phases (105 to 145, 145 to 180, 180 to 210, and 210 to market). The diet fed from 105 to 145 lb contained 6% added choice white grease. Diets fed during the other three phases did not contain any added fat. The total dietary lysine levels fed were 1.05, .83, .72, and .62 for the four phases, respectively. Supplemental selenium and iodine were provided at a rate of .3 ppm for the first phase and .2 ppm for the two remaining phases. All other nutrients met or exceeded the requirement estimates provided by NRC (1998). Vitamin levels were similar to KSU recommendations. Supplemental copper, zinc, iron, and manganese were provided as listed in Table 1. The levels provided in the control diet were similar to current Kansas State University recommendations. The next two diets provided 50 and 25%, respectively of the current recommendations. The last experimental treatment provided 50% of the recommended mineral levels during phase 1, and then no added supplemental trace minerals were provided in the last three phases.

Table 1. Amount (g/ton) of Supplemental Trace Minerals[a]

	Dietary Treatment			
Mineral	Control	50%	25%	Combination
Phase 1 (105 to 145 lb)				
Copper	15	7.5	3.75	7.5
Zinc	150	75	37.5	75
Iron	150	75	37.5	75
Manganese	36	18	9	18
Phases 2, 3, and 4 (145 to Market)				
Copper	10	5	1.25	0
Zinc	100	50	12.5	0
Iron	100	50	12.5	0
Manganese	24	12	4	0

[a]All diets contained 0.3 ppm of iodine and selenium during phase 1 and 0.2 ppm of iodine and selenium for subsequent phases.

Results and Discussion

No differences (P>.10) were observed for growth performance or carcass parameters (Table 2). Growth performance for this trial was excellent, with control pigs actually having the numerically lowest ADG and highest feed efficiency. The NRC (1998) recommendations for total dietary copper, zinc, iron, and manganese are 3, 45, 45, and 2 g per ton, respectively. Using the ingredient values listed for copper, zinc, iron, and manganese listed in the NRC (1998), a typical corn soybean meal-based finishing diet provides approximately 100% of the copper and iron requirements, 4 to 5 times the manganese requirement, and 40 to 50% of the zinc requirement. The lack of response in this experiment illustrates that the NRC requirements probably were already adequate for typical corn-soybean meal finishing diets. These results suggest that margins of safety for copper, zinc, iron, and manganese can be lowered significantly in swine finishing diets

without negatively affecting growth performance or carcass characteristics. Trials to confirm these results may need to be conducted with higher levels of disease or stress. Additionally, we did not measure any potential impact of the trace minerals on meat quality traits.

Table 2. Influence of Trace Mineral Supplementation on Growth Performance and Carcass Characteristics[a]

	Dietary Treatment				
Item	Control	50%	25%	Combination	SEM
ADG, lb	1.67	1.71	1.72	1.69	.03
ADFI, lb	4.50	4.50	4.53	4.52	.06
F/G	2.70	2.63	2.64	2.68	.04
Market weight, lb	254.1	253.9	256.9	255.8	3.6
Fat depth, in	.74	.75	.75	.75	.02
Loin depth, in	2.23	2.27	2.22	2.24	.04
Percent lean, %	54.1	54.1	54.0	54.1	.3
Fat free lean index, %	49.1	49.0	49.1	49.1	.2

[a]Values represent the means of 11 pens (observations) per treatment with 25 pigs per pen. Pigs averaged 100.6 lb initially. No differences were observed among treatment groups (P>.10).

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EXAMINATION OF STOCKING DENSITY AND MARKETING STRATEGIES IN A COMMERCIAL PRODUCTION ENVIRONMENT[1]

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Summary

The influence of stocking density (7.4 or 6.6 sq ft per pig) and marketing strategy (0, 1, or 2 sorts before closeout) was examined in a commercial production environment. No interaction between stocking density and marketing strategy was observed. Higher stocking density had no negative effects on growth performance or carcass characteristics. The major advantage of one or two sorts was a reduction in sort loss of $.27/cwt carcass ($.52/pig) compared to no sorts. No differences were found between one and two sorts under the packer matrix used in this study.

(Key Words: Stocking Density, Growth Marketing, Carcass Characteristics.)

Introduction

The influence of stocking density on growth has been characterized relatively well and indicates that growth rate is slower because of reduced feed intake as pigs are raised in more crowded conditions. However, economic analysis usually indicates that the more crowded conditions result in lower fixed facility costs. This is because the greater throughput from additional pigs offsets the decreased growth. Marketing strategy is highly dependent on the premium and weight discount grid for a particular packer. Marketing multiple times from a barn incurs added sorting costs. The removal of pigs from a pen prior to closeout may have both positive and negative biological effects on the performance of the remaining pigs in the pen. A positive effect may result from the reduced stocking density and a negative effect from the reestablishment of social order.

Therefore, our objective was to examine the interaction between stocking density and marketing strategy on growth performance and carcass characteristics.

Procedures

A total of 1,272 pigs (PIC C-22 × 337) was used in this experiment. Pigs were housed in a 48-pen finishing barn. Pens were blocked according to location in the barn and randomly assigned to treatment within block. The pigs initially averaged 64.6 lb. The trial was a 2 × 2 × 3 factorial randomized complete block design. The main effects were gender, stocking density, and marketing strategy. The two stocking densities were 25 (7.4 sq ft) or 28 (6.6 sq ft) pigs per pen at initial placement. The three marketing strategies were: a control treatment in which all pigs were marketed at the same time; a second treatment in which the heaviest four pigs per pen (visual appraisal) were marketed 21 d prior to closeout (1 sort); and a third treatment in which the heaviest two pigs per pen were marketed at 27 d, and the heaviest three

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pigs were marketed at 14 d prior to closeout (2 sorts).

The finishing barn was a double curtain-sided, deep pit barn. It operates on natural ventilation during warm weather and is equipped with automatic ventilation for cold weather. The floor was totally slatted concrete. Pens were equipped with one 4-hole self-feeder and one cup waterer. Pen dimensions were 10 ft × 18.5 ft to provide 7.4 and 6.6 sq ft per pig for pigs housed 25 and 28 pigs per pen, respectively. Pen size or number was not adjusted if a pig died or was removed from that pen.

Group weights of all the pigs in each pen were obtained every 2 weeks. Diet phase changes occurred at 4-week intervals. Feeders were vacuumed on the day that diet phases were changed, and the remaining amounts of feed recorded. Pigs in all pens were weighed at market before shipping to the processing plant. The pigs in each pen were marked with a different tattoo prior to marketing to allow carcass data to be collected and attributed back to each pen. Standard carcass criteria were measured including carcass weight, fat depth, loin depth, lean percentage, and fat-free lean index. The proportion of top market pigs was calculated. These were pigs that were acceptable to the packers. Acceptability was based on weight (> 165 lb) and absence of physical deformities.

All diets were corn-soybean meal based. Diets were formulated in five phase weight ranges for each gender consisting of 60 to 105, 105 to 145, 145 to 180, 180 to 210, and 210 lb to market for phases one to five, respectively. For the first two phases, 90 lb per pig of each diet were fed, then 100 lb per pig were fed in the next two phases, and the last phase until market. The diets fed during phases one, two, and three contained 6% added choice white grease. Diets fed during the other phases did not contain any added fat. The total dietary lysine levels fed were 1.22, 1.05, .90, .72, and .62 for barrows and 1.22, 1.10, .95, .75, and .65 for gilts for the five phases, respectively. Vitamin and trace mineral levels were similar to KSU recommendations.

Results and Discussion

No 2- or 3-way interactions were detected between stocking density and marketing strategy. Therefore, main effect means are listed in Table 1. As expected, there were several significant differences occurred between barrows and gilts for growth performance. The effects of stocking density and marketing strategy can be compared to the magnitude of the gender effect to gauge the relative strength of these effects.

As expected, the average total pen weight was heavier ($P<.05$) for the pens initially stocked with 28 pigs compared to the pens stocked with 25 pigs. On d 90 when the first pigs were marketed, the barrow pens tended ($P<.08$) to be heavier than the gilt pens. The pens initially stocked with 28 pigs were approximately 600 lb heavier ($P<.01$) than the pens stocked with 25 pigs on d 90. The total weight of pigs in the pen sold as tops was greater ($P<.01$) for barrows compared to gilts and for pens with 28 pigs compared to those with 25 pigs. Also as expected, the average numbers of pigs per pen on d 90 and sold as tops at market were higher ($P<.01$) for the pens initially stocked with 28 pigs compared to those with 25 pigs. Survivability at d 90 was not influenced by treatment. The percentage of barrow that reached acceptable market weight (tops) was higher ($P<.05$) compared to gilts. Because survivability was similar across gender to d 90, this indicates that a greater number of gilts were classified as culls because of light weight at market.

Barrows had a greater ($P<.05$) average weight on d 90 and for pigs sold as tops compared to gilts. The marketing strategy without sorting resulted in heavier ($P<.05$) pigs at market compared to the two-sort strategy, and the one-sort strategy resulted in intermediate weight pigs. The heavier average pig weight was caused by the heavy weights attained by the fastest growing pigs in this treatment. These faster growing pigs were sorted and marketed earlier in the one-

and two- sort treatments. Barrows grew faster (P<.05) than gilts from d 0 to 90. From d 90 to the last day that pigs were in the barn (d 117), pigs on the no-sort strategy grew slower (P<.05) compared to pigs in the one-sort strategy, and the pigs in the two-sort strategy had intermediate ADG.

Also as expected, gilts had less fat depth, larger loin depth, and a greater percent lean (P<.05) than barrows. In contrast, the number of pigs per pen or marketing strategy had no influence on carcass characteristics. Because they were leaner, the gilts had a higher (P<.05) lean premium. However, the no- sort marketing strategy did result in a higher (P<.05) sort loss penalty compared to the other two strategies. The sort loss or weight discount for the no-sort strategy probably was due to heavy weight pigs being out the top range of the packer matrix. The two-sort strategy appears to lack any advantage over the one-sort strategy and, in fact, may be detrimental to growth performance.

In general, the increased number of pigs per pen in the high stocking density group had little effect on survivability, number of tops, growth performance, or carcass value. Several other research reports have established that growth rate decreases linearly as stocking density increases. Although we did not observe a difference in our study, we believe that the difference in the square footage of the two treatments was not large enough to elicit a detectable response. Nonetheless, the increased pounds of pork produced per square foot of facility will lower fixed cost by approximately $1.50 per pig. This assumes a facility cost of $36 per 7.4 sq ft. The increased number of pigs per pen in this study lead to a significant reduction in fixed costs with no detectable influence on growth performance.

Producers and veterinarians often argue that increased stocking density will aggravate disease outbreaks or other environmental stresses. However, recent research suggests that multiple stresses are additive and not antagonistic and that the crowding will not aggravate disease outbreaks.

It is not surprising that the no- sort marketing strategy had the poorest growth performance from d 90 to 117, likely because these pigs became more crowed as they gained weight. However, the two-sort strategy with the potentially least crowed treatment group had intermediate ADG. We speculate that two sorts led to more disruption in social order but gained some benefit of the decreased crowding. The percentage of tops increased numerically with the number of sorts. Thus, even though average weight of the tops decreased significantly, similar total pounds of tops were marketed from each pen. This study illustrates that marketing strategy can impact growth performance and weight discount during the marketing period but has little effect on carcass characteristics.

Table 1. Influence of Gender, Pigs per Pen, and Marketing Strategy on Performance and Market Returns

	Gender		Pigs/Pen			Sorts[a]			
Item	Barrow	Gilt	25	28	SEM	0	1	2	SEM
Pen Weight, lb									
d 0	1,714	1,713	1,616[b]	1,810[c]	1	1,711	1,714	1,715	2
d 90	5,534	5,368	5,143[b]	5,758[c]	65	5,403	5,490	5,460	80
Tops at market	6,227[b]	5,811[c]	5,677[b]	6,362[c]	93	5,955	6,031	6,072	114
Inventory									
d 90, pigs/pen	25.3	25.1	23.7[b]	26.7[c]	0.3	24.8	25.3	25.4	0.4
Tops, pigs/pen	23.9	22.8	21.9[b]	24.8[c]	0.4	22.8	23.5	23.8	0.5
Survivability to d 90, %	95.6	94.6	94.8	95.4	1.1	93.7	95.7	95.9	1.3
Tops, %	90.2[b]	86.2[c]	87.8	88.6	1.4	85.9	88.7	89.9	1.8
Average Pig Weight, lb									
d 90	218.6[b]	214.3[c]	217.1	215.9	1.3	217.9	216.7	214.8	1.5
Tops at market	261.0[b]	254.6[c]	258.8	256.8	2.1	262.2[b]	256.5[bc]	254.7[c]	2.5
D 0 to 90									
ADG, lb	1.71[b]	1.66[c]	1.69	1.68	0.01	1.70	1.69	1.67	0.02
D 90 to 117									
ADG, lb	1.49	1.43	1.48	1.44	0.03	1.40[b]	1.52[c]	1.47b[c]	0.04
ADFI, lb	5.57[b]	5.14[c]	5.39	5.32	0.07	5.27	5.41	5.39	0.08
F/G	3.75	3.63	3.65	3.73	0.07	3.78	3.59	3.70	0.09
Carcass Characteristics									
Fat depth, in	0.69[b]	0.54[c]	0.62	0.61	0.01	0.61	0.62	0.61	0.01
Loin depth, in	2.30[b]	2.40[c]	2.36	2.34	0.02	2.36	2.33	2.35	0.02
Lean, %	55.20[b]	57.70[c]	56.40	56.50	0.10	56.50	56.30	56.60	0.10
Fat-free lean index	49.90[b]	51.50[c]	50.70	50.70	0.10	50.80	50.60	50.70	0.10
Carcass Value									
Lean premium, $/cwt	4.33[b]	6.01[c]	5.14	5.20	0.07	5.22	5.04	5.26	0.09
Sort discount, $/cwt	0.66	0.49	0.61	0.54	0.07	0.76[b]	0.49[c]	0.48[c]	0.08

[a]Marketing events occurred on d 90, 103, and 117 for groups with two sorts, on d 96 and 117 for groups with one sort, and d 117 for groups with no sorts.

[b,c]Means within row and main effect of gender, density, or sort are different.

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