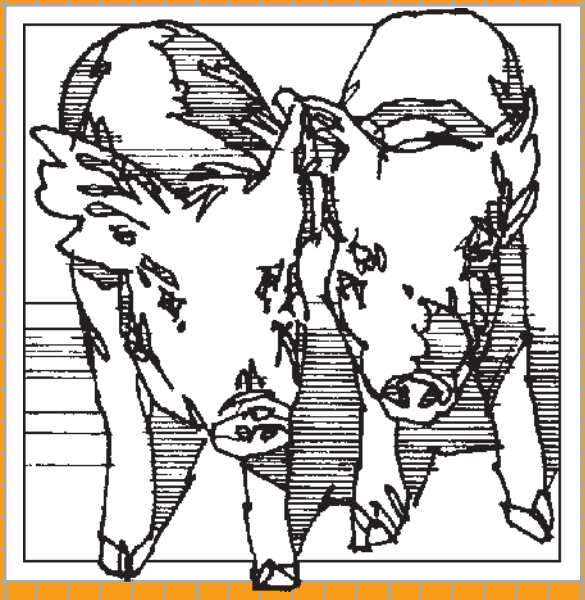


K-STATE
Kansas State University

SWINE DAY 2000

REPORT OF PROGRESS 858, KANSAS STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

FOREWORD

It is with great pleasure that we present to you the 2000 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, 2000 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)	mo	=	month(s)
			GE	=	gross energy	µg	=	microgram(s)
avg	=	average	h	=	hour(s)		=	.001 mg
BW	=	body weight	in	=	inch(es)	N	=	nitrogen
cm	=	centimeter(s)	IU	=	international unit(s)	ng	=	nanogram(s)
CP	=	crude protein					=	.001 µg
CV	=	coefficient of variation	kg	=	kilogram(s)	no.	=	number
			Kcal	=	kilocalorie(s)	ppm	=	parts per million
cwt	=	100 lb	lb	=	pound(s)	sec	=	second(s)
d	=	day(s)	Mcal	=	megacalorie(s)	SEW	=	segregated early weaning
DM	=	dry matter	ME	=	metabolizable energy			
°F	=	Fahrenheit						
F/G	=	feed efficiency	mEq	=	milliequivalent(s)	wk	=	week(s)
ft	=	foot(feet)	min	=	minute(s)	wt	=	weight(s)
ft^2	=	square foot(feet)	mg	=	milligram(s)	yr	=	year(s)

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

KSU VITAMIN AND TRACE MINERAL PREMIXES

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

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

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

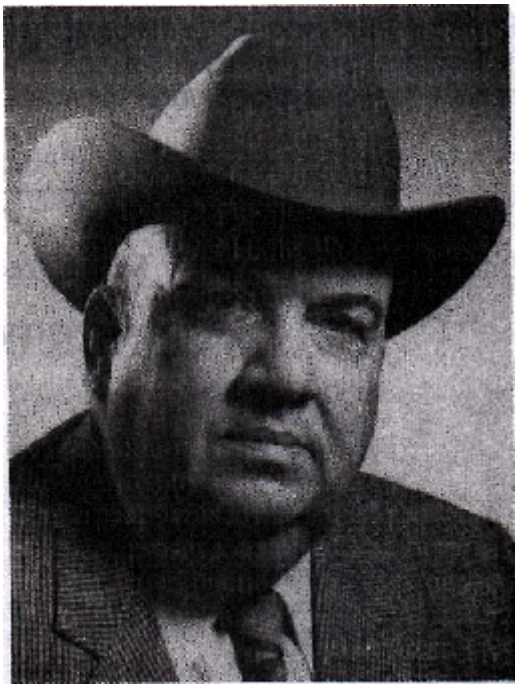
Sow add pack: each lb of premix contains choline, 100,000 mg; biotin, 40 mg; folic acid, 300 mg; and pyridoxine, 2,750 mg.

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.

Robert H. "Bob" Hines



Bob Hines was born on November 20, 1935, in Sheridan, Indiana, the oldest of three children born to Hess and Louise Hines. The family operated a general hog farm, and Bob exhibited a love for the swine industry from the very beginning. He was a 4-H club member for 10 years and a State Farmer in FFA. He was a member of both livestock and dairy judging teams that won state championships in Indiana. Bob attended and graduated from Purdue. While there, he was a member of the livestock judging team and was high individual at the International Livestock Judging Contest in Chicago. Following graduation Bob spent two years as an officer in the Army Transportation Corps (1957-1959). Then he entered Michigan State University to work on a Masters degree, which he completed in 1961. During the time he was working on his M.S. degree, he held the rank of assistant instructor. Once the degree was finished, he was appointed an instructor at Michigan State and served as State Swine Extension Specialist as well as coach of the livestock judging team. He finished his Ph.D. degree in 1966.

Bob became a part of the Kansas State University Animal Husbandry Department in 1966. During his tenure, he has taught four courses (Animal Science Laboratory, Livestock and Meat Evaluation, Livestock Production Management, and Swine Science) with a total enrollment of 5,461 students. He was assigned as coordinator and supervisor of the KSU Swine Teaching and Research Herd in1966, a duty he held for 25 years. Many students, both undergraduate and graduate, have had the benefit of Bob's counsel as advisor or major professor. He has advised 20 to 30 undergraduates a year, has been major professor for 22 graduate students, and has served on committees for 52 other graduate students. Bob coached the livestock judging teams in 1967 and 1969. He also has served as advisor for the Block and Bridle Club and Alpha Zeta.

The primary emphasis in his research has been swine management and swine nutrition. The management investigations have involved work on such subjects as the evaluation of feeding systems, pig behavior in these systems, open-front buildings, cooling systems, and space needs of pigs finished to heavier weights.

Nutrition studies have included evaluation of grain sources, alternative energy sources for growing-finishing pigs, protein levels and amino acid supplementation, calcium-phosphorus requirements for boars and gilts, and evaluation of feed additives. Bob has authored or co-authored over 75 scientific research papers as well as over 160 research articles that have appeared in previous Swine Day Reports.

Bob is one of the most, if not the most, influential swine judges in the United States. During the past 43 years, he has judged hog shows throughout the United States. This includes all types of shows from small county fairs to large national breed shows. One of his co-workers has observed "Bob often brought a voice of moderation to the show ring". He has worked closely with the Kansas purebred swine industry and the KPPC. He is also a strong supporter of performance testing having served during his career as supervisor and manager of both the Michigan and Kansas swine test stations. For five years, he was on the Board of Directors of the SENEK swine testing station at Wymore, Nebraska. Bob also has been a director on the board for the National Chester White Swine Record Association and was president of that group from 1982 to 1984.

From 1973 to 1983, Bob was a co-owner of Sunflower Chesters, a herd of 100 Chester White and 10 Hampshire sows. The farm held four production sales a year. Since 1990 Bob has owned and operated Prairie Land Genetics, a herd of 40 Hampshire sows. The herd produces breeding stock and 4-H and FFA show pigs. During this past year, Bob bred, fitted, and showed both the grand champion boar and female at the National Hampshire Swine Type Conference.

Bob is known affectionately as "Boss Hog" to literally thousands of former students and swine producers around the country. His understanding and knowledge of the swine industry are reflected in his teaching, research, and production efforts. As a result, he is loved, admired, and respected by those who have met and worked with him. We wish Bob and wife Treva many happy and productive years in their retirement.

CONTENTS

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 2000

MARKET VERSUS FORMULA-DERIVED PRICES FOR SEGREGATED EARLY-WEANED PIGS

K. C. Dhuyvetter[1]

Summary

A formula for deriving the price of segregated early-weaned (SEW) pigs using prices of grain, soybean meal, and market hog was estimated based on return on investment being equal for all three phases of production—farrowing, nursery, and finishing. The USDA- reported SEW pig prices were compared with formula-derived prices. The level of correlation between these two series was sensitive to how prices of grain, soybean meal, and market hog were chosen. Using expected prices in the formula resulted in SEW prices that were correlated strongly with reported market prices. Using hindsight cash prices in the formula resulted in SEW formula prices that were correlated weakly with reported prices. This approach may be appropriate with contractual relationships where the goal is to share profits and losses proportionately. Thus, the manner in which the formula is used (i.e., method of choosing prices) will depend on the risk attitudes of the buyer and seller, as well as the nature of their business relationship.

(Key Words: SEW Prices, Formula Prices, Marketing.)

Introduction

The decade of the 1990's saw many structural and technological changes in the swine industry. The practice of separating farrow-to-finish production into three distinct phases at multiple locations was one such change. Producers also widely adopted the practice of weaning pigs at an early age. The practice of segregated early weaning (SEW) was developed because it produces healthier, more efficient pigs and helps maximize genetic potential of breeding stock. As SEW practices were adopted, a new problem emerged – what was the value of these pigs? By definition, SEW pigs are kept separate from other pigs. Thus, marketing them through traditional auction barns where buyers and sellers meet to "discover a price" was not a viable option.

Because no market price quote existed for SEW pigs and negotiating price for each transaction was costly and time-consuming, buyers and sellers looked for pricing formulas to place a value on these pigs. Numerous formulas were developed ranging from a flat price of $30 to $32 per head to more complex formulas where price is a function of prices for live (finished) hogs, corn, and soybean meal. For additional information on SEW formula prices see *Estimating the Value of Segregated Early Weaned Pigs* (K-State Res. and Ext. MF-2221) or *Pricing Early-Weaned Pigs* (NPPC).

In the fall of 1997, the U.S. Department of Agriculture (USDA) Agricultural Marketing Service (AMS) began collecting and publishing a weekly price report on weaned pigs and feeder pigs. The report attempts to exclude contract sales and deal with cash market trades only. The report lists high, low, and average prices by lot size (<250 head, 250-750 head, and >750 head) as well

[1]Department of Agricultural Economics.

as a weekly composite price. The report can be accessed on the Internet at:

http://www.ams.usda.gov/mnreports/NW_LS255.txt.

Now that price quotes for SEW pigs are publicly available, there may not be a need for a complex formula. In this case, a formula could simply be the USDA price quote for SEW pigs (perhaps with some local basis adjustment). However, not all buyers and sellers can use this approach, because somebody has to "discover" the price that is quoted by USDA. Additionally, even though prices change over time to reflect changing market conditions, one segment of the industry is often more or less profitable than another segment at any given time. In other words, profitability generally is not distributed equally across segments of the industry at a point in time. For example, producers selling SEW pigs sometimes realize higher returns than those buying SEW pigs and vice versa. However, producers that have long-term contractual relationships to buy and sell SEW pigs from each other may want a formula for valuing pigs that more closely reflects the actual costs and returns associated with the different phases of production (i.e., a "profit sharing" approach).

This study compared the prices for SEW pigs as reported by USDA with a formula-derived price, where the formula was based on equal returns to the different phases of production. Alternative methods for valuing input variables in the formula also were compared.

Procedures

Projected budgets based on full economic costs were developed for the farrowing, nursery, and finishing phases of a commercial swine operation. The budget for the farrowing phase was based on a 1,200-sow operation marketing 19 10-lb pigs/sow/year. Nursery and finishing phase budgets were based on 1,200-head barns with average feed efficiency (lbs of feed per lb of gain) of 1.8 for the nursery phase and 3.1 for the finishing phase. Pig selling weights were 10, 55, and 260 lbs for the farrowing, nursery, and finishing phases, respectively.

Using the budgets for each production phase, prices for 10-lb weaned pigs and 55-pound feeder pig were set at levels that made return on investment exactly equal for all three phases. This process was repeated using weekly prices of corn, soybean meal, and market hog from 1990-1999. This allowed formulas to be estimated where SEW (weaned) and feeder pig prices were functions of grain, soybean meal, and market hog prices. The following are the estimated formula prices for feeder and SEW pigs:

(1) SEW pig price:
$$-2.308 - (1.6489 * GRN) + (0.05683 * GRN^2) - (0.045570 * SBM) + (0.00007443 * SBM^2) + (0.9981 * LH) - (0.00335 * LH^2) = \text{Price of 10-lb. SEW pig, \$/head}$$

(2) Feeder pig price:
$$-0.616 - (2.3343 * GRN) + (0.02558 * GRN^2) - (0.025723 * SBM) + (0.00002081 * SBM^2) + (1.1496 * LH) - (0.00122 * LH^2) = \text{Price of 55-lb. feeder pig, \$/head}$$

where, GRN is grain price ($/cwt), SBM is soybean meal price ($/ton), and LH is market hog price ($/cwt, carcass weight). Discussion hereafter pertains to the SEW pig formula).

Weekly composite market prices quoted by USDA-AMS from 11/97 to 6/00 were compared to formula-derived prices for SEW pigs to determine how well these two price series are correlated. The following alternative methods of choosing formula values for grain, soybean meal and market hog prices were considered:

1. Futures-based price expectations for GRN, SBM, and LH (SEW price is established when SEW pig is sold). This method values SEW pigs in "real-time."

2. Observed cash prices for GRN, SBM, and LH (SEW price is established when market hog is sold). This method values SEW pigs in "hindsight."

Results and Discussion

The SEW formula-derived prices calculated using futures-based price expectations (method 1) are compared to USDA quoted market prices in Figure 1. In this case, all variables in the formula (i.e., GRN, SBM, and LH) were expectations (futures prices adjusted for expected basis) at the time the SEW pig was sold. For example, LH is the expected price of a market hog at the end of the finishing phase, and GRN and SBM are the expected average prices for corn and soybean meal over the nursery and finishing phases. The SEW formula-derived price and the USDA-quoted market price have a correlation of 0.87, suggesting that they follow each other quite well. However, formula prices tend to be smoothed out compared to USDA-quoted prices. For example, the minimum USDA-reported price over this time period was $14.66 per head compared to $18.31 for the formula price. Likewise, the maximum reported price was $40.93 per head compared to a maximum formula price of $38.66. This difference suggests that market participants are more optimistic when prices are high and more pessimistic when prices are low.

The second method of choosing values for GRN, SBM, and LH to plug into the formula was to use observed cash prices for all three variables (i.e., the hindsight approach). Figure 2 compares the formula-derived prices with USDA-reported prices using this method. Here, GRN and SBM prices are the averages of the cash and soybean meal prices for 50 weeks prior to the market hog being sold as a proxy for average feed prices during the entire production process (i.e., from breeding to market), and LH is the cash price for the week when the market hog is sold. Using the formula in this manner results in SEW formula-derived prices that are only weakly correlated with USDA-quoted prices (correlation = 0.27). This is not unexpected, because this approach estimates the price at which both parties (farrower and finisher) share returns proportionately, whereas the market price allows for one party to be more profitable than the other at any given point in time. A potential problem with using the formula in this manner (i.e., hindsight) is that the seller of the SEW pigs most likely would want to be paid when the pigs are delivered rather than wait until they are sold as market hogs. A possible solution to this problem would be to have an estimated payment when the pigs are delivered and then "settle up" once all prices are known. However, this would complicate the process somewhat.

Given the tremendous variability in the formula-derived SEW prices displayed in Figures 1 and 2, a logical question arises. Which price is the most appropriate? The answer to that question depends on why the formula is being used. First, if the formula is being used to "discover a price," it may not even be needed now that a market price is quoted publicly. However, if the formula is being used to estimate what a reasonable spot price might be, then the approach used in Figure 1 (i.e., use of expected prices for GRN, SBM, and LH) appears to be reasonable. On the other hand, if the purpose of the formula is to arrive at a price for a long-term contractual relationship where the goal is to share returns between the buyer and seller proportionately, then the approach used in Figure 2 (i.e., use of observed prices for GRN, SBM, and LH) may be more appropriate. However, it is important to recognize that, in this case, the price determined at a given point in time may vary considerably from quoted market prices and also that this price is not known until the SEW pig has been finished.

Another consideration is the impact the different formula approaches have on the relative market risk to the different parties. Method 1 that used expected prices results in less risk for the farrower but more for the finisher. On the other hand, method 2 that used hindsight cash prices results in more risk to the farrower and less risk for the finisher. Thus, the risk attitudes of the buyer and seller as well as their business relationship may dictate which approach is used.

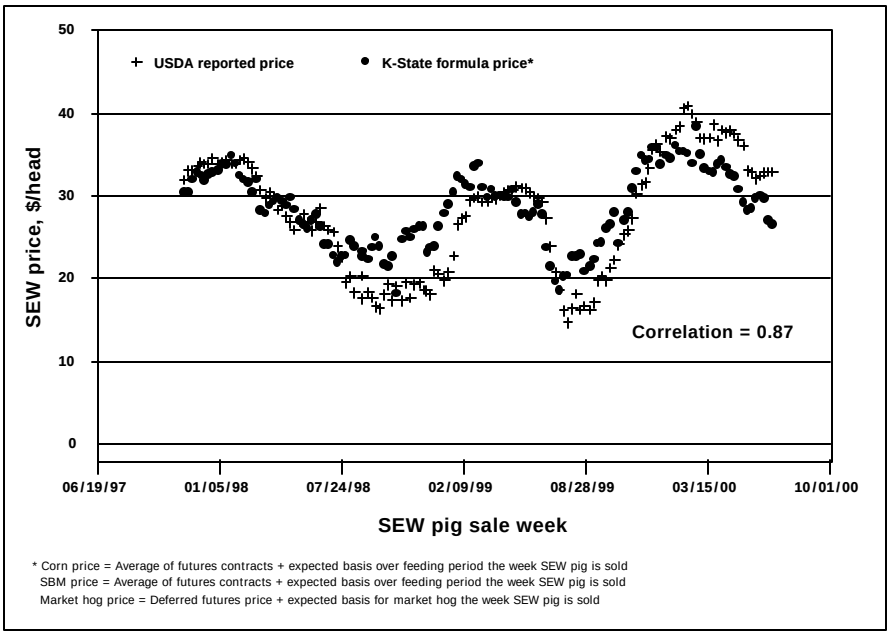


Figure 1. Comparison of USDA Quoted SEW Prices to K-State Formula-Derived Prices (method 1 – grain, soybean meal, and market hog prices based on deferred futures prices adjusted for basis).

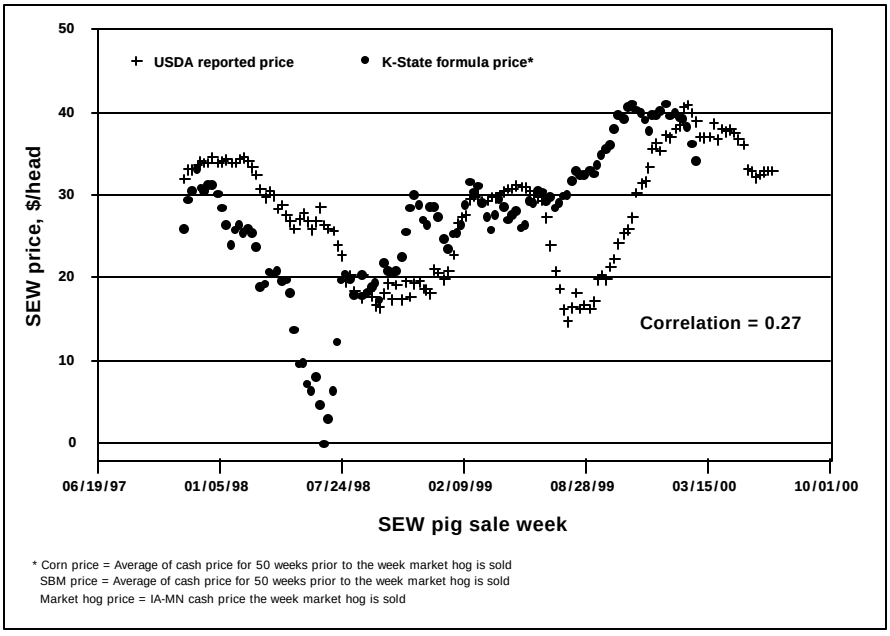


Figure 2. Comparison of USDA Quoted SEW Prices to K-State Formula-Derived Prices (method 2 – grain, soybean meal, and market hog prices based on hindsight cash prices).

OPTIMAL PARITY DISTRIBUTION – WHEN IS THE BEST TIME TO CULL SOWS?

K. C. Dhuyvetter[1]

Summary

The economic impact of alternative sow-culling strategies was examined by simulating costs and returns for a farrowing-to-weaning swine operation. Culling strategies considered were to sell sows after parity 1 (P1) through parity 10 (P10). These 10 culling strategies resulted in different parity distributions. The optimal parity distribution is a complex issue, because it is related to conception rates, litter size, feed intake, as well as other factors. Results of this analysis indicate that the most economical time to cull a sow is after her eighth or ninth parity. This results in a breeding herd comprised of 18 to 20% gilts and a herd average parity of 3.5 to 4.0. However, the additional benefits of keeping a sow beyond about six parities are relatively small. The optimal time to cull a sow decreases as the cost of replacement gilts increases and vice versa. Feed costs impact the level of costs and returns but have very little impact on the optimal parity distribution. Similarly, over a range of conception rates and litter sizes, the optimal time to cull a sow is relatively constant.

(Key Words: Parity Distribution, Culling, Farrowing-to-Weaning, Economics.)

Introduction

From perspectives of both the industry and the individual producer, producing a high quality product at the lowest cost possible is important. Numerous factors impact the cost of production, and many of these factors are interrelated. However, to quantify the impact of a specific factor that requires a management decision, an economic analysis must focus on this key factor. Specifically, this research examined the impact sow attrition rate has on the cost and returns of producing a weaned pig. This information is useful for producers as they identify strategies for culling sows that best fit their operations.

It has been suggested that 15 to 20% of a breeding herd should be comprised of gilts and that the herd average parity should be 2.5 to 3.0. However, the economic consequences of varying from this optimal parity distribution (OPD) have not been quantified. Quantifying the economic costs and returns associated with sow attrition is complicated because of the many interacting factors. This may be one reason why OPDs have not been quantified in terms of costs and returns. This analysis identifies key factors affecting OPD, how sensitive OPD is to these factors, and what the cost is of not being at the OPD.

Procedures

Projected budgets based on full economic costs were developed for sow operations that cull sows after their first through their tenth parities to identify the optimal parity distribution. Each of these 10 budgets or scenarios represents a different parity distribution. For example, an operation that culls sows after their first parity would be a gilt farm with 100% one-parity sows. Similarly, an operation that culls all sows after their second parity would be comprised of only one- and two-parity sows. On the other hand, an operation that does not cull sows until after their tenth parity would have a distribution of first-parity through tenth-parity sows.

[1]Department of Agricultural Economics.

Numerous assumptions were required in order to construct budgets for the 10 different sow-culling strategies (i.e., parity distributions). The following are some of the key assumptions made that impact costs and returns.

- Weaned pig value is constant by parity.
- 220 farrowings occur every 4 weeks.
- Cost of a replacement gilt is $200/head.
- Sow cull income varies by weight of the sow only. Gilts not conceiving are sold at a higher price.
- Sow death loss is 4% for first parity sows and increases linearly by 0.33% for each successive parity.
- Genetic charge is based on the cost of replacement gilt, the salvage value of cull sow, and the replacement rate.
- Feed costs are $143/ton and $134/ton for lactation and gestation diets, respectively (based on 5-year average prices).
- Feed consumption varies by parity. Gestation intake ranges linearly from 5.15 to 6.00 lbs/head/day for parities 1 through 10. Lactation intake ranges nonlinearly from 10.25 to 12.55 lbs/head/day for parities 1 through 10.
- Total costs for labor, repairs, utilities, and professional fees are constant across strategies. However, these costs on a per-weaned-pig basis do vary based on production.
- Costs for marketing and transportation and veterinary, drugs, and supplies are constant on a per-weaned-pig basis.

Two other major assumptions affect the costs and returns – conception rates and pigs weaned per litter. Assumed conception rates for gilts and sows by parity level are shown in Figure 1. Conception rate as a percent of original gilt numbers is slightly below 80% for gilts and then decreases to approximately 20% by the tenth parity. Conception rate as a percent of the previous parity is constant at 86%. The ability to get sows bred back plays a significant role in the optimal parity distribution. Therefore, the sensitivity of costs and returns to the conception rate assumption was examined.

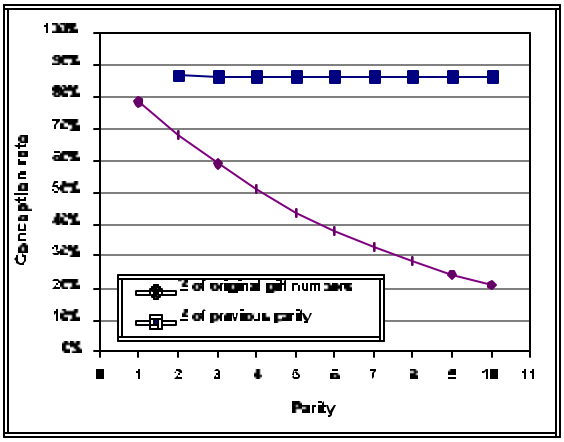


Figure 1. Conception Rate by Parity.

Another major assumption impacting the OPD is pigs weaned per sow by parity. Pigs weaned per sow is a function of pigs born alive and preweaning mortality. Figure 2 shows the levels of pigs born alive and preweaning mortality by parity used in the analysis. The relationship between pigs born alive per litter and parity was estimated from previous research data – studies spanning multiple countries and decades – and indicates that pigs born alive is maximized at the sixth parity. Preweaning mortality was based on several studies and combined with pigs born alive to give pigs weaned per litter by parity, which was used to calculate costs and returns for each of the 10 parity distributions examined. Similar to conception rate, pigs weaned per litter by parity will impact the optimal parity distribution, so the sensitivity of costs and returns to this relationship was examined.

Given the assumptions listed, the production and cost and returns were estimated for each of the 10 different strategies for culling sows. All analyses were based on steady state production. That is, the swine operation was assumed to be operating at a point where the sow herd size is constant from month to month (i.e., gilts purchased exactly equaled sows culled and sow death loss).

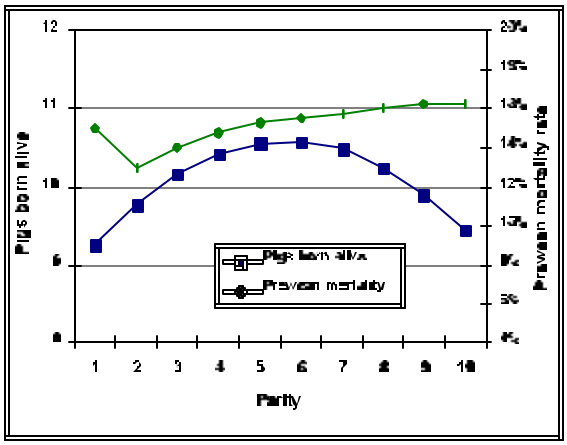


Figure 2. Sow Production per Litter by Parity.

Results and Discussion

Table 1 reports the production information for the different sow-culling strategies. Based on the assumptions, in order for producers to achieve a parity distribution with less than 20% gilts, they need to keep sows that breed back for at least 8 parities. The total pigs weaned/sow/year is maximized when sows are kept for 8 parities; however, differences between culling sows after 5 through 10 parities are quite small. Given the production information in Table 1, costs and returns can be estimated allowing for the most profitable sow culling strategy (i.e., parity distribution) to be identified.

Costs and returns of the 10 sow-culling strategies are given in Table 2. As expected, selling sows after their first parity (i.e., a gilt farm) is extremely unprofitable because of the high sow depreciation cost. The cost of producing a weaned pig decreases at a decreasing rate as sows are kept for additional parities. The total cost of producing a weaned pig is minimized when sows are kept through 8 or 9 parities before culling. However, for sows kept between 6 to 10 parities, the difference in cost is less than 40¢ per head. Based on the assumptions used, returns per head are approximately twice as high when sows are kept for 7 to 10 parities before culling (average of $2.95/head) compared to culling after four parities ($1.45/head).

A sensitivity analysis was conducted to determine how changing various cost assumptions impacted returns over total costs (i.e., line F in Table 2). Because differences in breeding herd depreciation cost was the greatest, several gilt-replacement costs were considered. If replacement gilts are valued at $150 per head (original assumption was $200), returns were still maximized when sows are kept for 8 parities (Table 3). However, with these lower gilt prices, the advantage in returns for sows kept for 7 to 10 parities (average of $4.54/ head) compared to sows kept for 4 parities ($3.91) is less than half of what it was when gilts were valued at $200 per head. On the other hand, with gilts valued at $250 per head, keeping sows for 9 parities maximizes returns. At this higher gilt price, the advantage in returns for sows kept for 7 to 10 parities (average of $1.37/head) compared to sows kept for 4 parities (-$1.02) increases almost a dollar per head compared to when gilts were valued at $200 per head. Although returns were maximized in all cases with sows kept for 8 or 9 parities, the advantage of doing so increases (decreases) as the price of replacement gilts increases (decreases).

Costs for both the gestation and lactation diets were varied by +/- 25% to determine how sensitive returns are to feed costs (Table 3). Although increasing or decreasing feed costs impacts the level of returns, it has almost no impact on relative differences between parity distributions. As feed costs increase, the optimal culling strategy is to sell sows slightly quicker, and when feed costs decrease, the optimal strategy is to keep sows a little longer. However, the changes are quite small. Therefore, from a management perspective, the optimal sow-culling strategy is basically invariant to feed costs, even though absolute returns are very sensitive to them.

Cost and return results presented in Tables 2 and 3 were based on the pigs weaned per litter and conception rate relationships with parity displayed in Figures 1 and 2. Because these factors have major impacts on economic returns, the relationships displayed in Figures 1 and 2 were modified to see what impact this had on optimal parity for culling sows.

Several alternative relationships between conception rate and parity were considered.

The first variation was to use the base conception rate (i.e., that shown in Figure 1) as well as conception rates that were +/- 10%. In other words, this answers the following question. What is the impact if the conception rate is higher or lower at every parity by 10% compared to the initial assumption? Another scenario considered the impact of starting at the same conception rate as the base scenario but decreasing at a faster or slower rate. In this scenario, conception rates were equal at parity 1, but then decreased to a level at parity 10 that was +/- 40% of the base scenario. Given these alternative scenarios, five conception rate-parity relationships were considered (base, base +10%, base –10%, +40% at P10, and –40% at P10). The steady state number of gilts purchased every month and the resulting parity distribution for each culling strategy were recalculated for each of these scenarios.

In addition to considering alternative conception rates, an alternative litter size by parity relationship was considered. The alternative was entirely hypothetical, because it was not estimated from previous research. The hypothetical scenario represents sows that reach their peak litter size at an earlier parity compared to the relationship displayed in Figure 1. Over 10 parities, the average litter size was held constant, but the distribution was changed. The reason for "shifting" the peak litter size to the left (i.e., at an earlier parity) was to see if this pattern in litter size by parity would result in optimal culling of sows after fewer parities.

The net returns per head for the various conception rate and litter size assumptions for the 10 different sow-culling strategies are given in Table 4. All cost and price assumptions are held constant at their original values. In the base scenario for both conception rate and litter size, returns were maximized when sows were culled after 8 or 9 parities (these are the same numbers as Line F in Table 2). At the alternative conception rates, returns also were maximized when sows were culled after either eight or nine parities. Additionally, when conception rates increased (base +10% and +40% at P10), the level of returns increased considerably. For example, with a strategy of culling sows after 8 parities, returns increased by 76¢ per head when conception rates increased 10% ($3.79 vs. $3.03). For an operation producing 24,000 pigs per year, 76¢ per head would equate to an increase in returns of $18,240. Similarly, by decreasing the rate of decline in conception rates between parities (i.e., +40% at P10), returns increased by 50¢ per head ($3.53 vs. $3.03). Likewise, when conception rates decreased (i.e., base –10% and –40% at P10), returns decreased considerably. Furthermore, the increases and decreases were not symmetric. That is, a 10% decrease in conception rates had a negative impact on returns that was much greater than the positive impact from a 10% increase in conception rates.

When the litter size assumption was changed to the hypothetical scenario, net returns were maximized with sows being culled after their eighth parity for all conception-rate scenarios. With the exception of sows culled after their first parity, the level of returns increased with the hypothetical litter size by parity relationship compared to the base scenario, because larger litter sizes occur at the lower preweaning mortality rates. The information in Table 4 shows that the level of returns varies with productivity, but the OPD is quite robust over the conception rate and litter size scenarios considered.

Table 1. Parity Distribution and Production from Sow Herd

	Parity prior to Culling[a]									
Item	1	2	3	4	5	6	7	8	9	10
Percent of farrowings from each parity (steady-state parity distribution)										
Parity 1	100.0	53.6	38.2	30.7	26.4	23.3	21.4	19.7	18.5	17.7
Parity 2		46.4	33.2	26.6	22.7	20.2	18.6	17.0	16.2	15.5
Parity 3			28.6	23.0	19.5	17.4	15.9	14.7	13.9	13.2
Parity 4				19.8	16.8	15.2	13.6	12.7	12.1	11.4
Parity 5					14.5	12.9	11.8	10.9	10.3	10.0
Parity 6						11.1	10.0	9.5	8.9	8.6
Parity 7							8.6	8.2	7.6	7.3
Parity 8								7.3	6.7	6.4
Parity 9									5.8	5.5
Parity 10										4.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average parity[b]	1.00	1.46	1.90	2.32	2.70	3.07	3.40	3.76	4.05	4.32
Sow inventory	1,220	1,196	1,188	1,184	1,184	1,182	1,182	1,179	1,179	1,180
Annual purchases	3,640	1,950	1,391	1,112	962	849	780	719	672	650
Replacement rate	298%	163%	117%	94%	81%	72%	66%	61%	57%	55%
Total litters/year[c]	2,860	2,860	2,860	2,860	2,860	2,860	2,860	2,860	2,860	2,860
Litters/sow/year	2.34	2.39	2.41	2.42	2.42	2.42	2.42	2.43	2.43	2.42
Pigs born alive/litter	9.25	9.49	9.68	9.83	9.93	10.01	10.04	10.06	10.05	10.03
Pigs weaned/litter	7.96	8.25	8.42	8.53	8.61	8.66	8.68	8.68	8.67	8.64
Pigs weaned/sow/year	18.7	19.7	20.3	20.6	20.8	20.9	21.0	21.1	21.0	20.9
Total pigs sold/year	22,756	23,599	24,078	24,399	24,614	24,758	24,823	24,839	24,792	24,704

[a]Represents the sow-culling strategy. For example, "3" indicates that sows are kept for three parities and then culled. Sows that do not breed back prior to their final parity are culled when they are open.

[b]Average parity is simply the weighted average parity. For example, the average parity for sows culled after their third parity is calculated in the following manner: (38.2% × 1 + 33.2% x 2 + 28.6% x 3) = 1.90.

[c]Based on 220 sows farrowing every 4 weeks.

Table 2. Cost-Return Budget for a Farrowing-to-Weaning Pig Operation

	Parity prior to Culling[a]									
Item	1	2	3	4	5	6	7	8	9	10
VARIABLE COSTS PER PIG SOLD:										
1. Grain	$4.09	$3.99	$3.98	$3.99	$4.02	$4.05	$4.10	$4.15	$4.21	$4.29
2. Protein	1.89	1.86	1.86	1.87	1.88	1.90	1.92	1.94	1.97	2.00
3. Base mix: vitamins, minerals, etc.	0.98	0.96	0.96	0.96	0.97	0.97	0.98	1.00	1.01	1.03
4. Pig starter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5. Feed processing	0.56	0.54	0.54	0.54	0.55	0.55	0.56	0.56	0.57	0.58
6. Labor	7.25	6.99	6.85	6.76	6.70	6.66	6.65	6.64	6.66	6.68
7. Veterinary, drugs, and supplies	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8. Utilities, fuel, and oil	1.32	1.27	1.25	1.23	1.22	1.21	1.21	1.21	1.21	1.21
9. Transportation and marketing costs	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10. Building and equipment repairs	1.18	1.13	1.10	1.08	1.07	1.07	1.06	1.06	1.06	1.07
11. Breeding/genetic charge										
a. Depreciation	16.83	7.54	4.87	3.67	3.06	2.63	2.38	2.18	2.02	1.97
b. Semen	2.01	1.94	1.90	1.88	1.86	1.85	1.84	1.84	1.85	1.85
c. Interest	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.78	0.79	0.79
d. Insurance	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
12. Professional fees (legal, accounting, etc.)	0.53	0.51	0.50	0.49	0.49	0.48	0.48	0.48	0.48	0.49
13. Interest on 1/2 variable costs	0.82	0.60	0.53	0.50	0.49	0.48	0.48	0.47	0.47	0.48
A. TOTAL VARIABLE COSTS	$40.34	$30.20	$27.21	$25.83	$25.17	$24.72	$24.53	$24.39	$24.38	$24.51
FIXED COSTS PER PIG SOLD:										
14. Depreciation on bldgs and equip	4.21	4.02	3.92	3.87	3.83	3.81	3.80	3.79	3.80	3.81
15. Interest on bldgs and equip	3.16	3.02	2.95	2.90	2.88	2.86	2.85	2.85	2.85	2.86
16. Insurance and taxes on bldgs and equip	0.78	0.74	0.73	0.72	0.71	0.71	0.70	0.70	0.70	0.71
B. TOTAL FIXED COSTS	$8.14	$7.78	$7.60	$7.49	$7.42	$7.37	$7.35	$7.34	$7.35	$7.38
C. TOTAL COSTS PER PIG SOLD	$48.48	$37.98	$34.81	$33.32	$32.60	$32.10	$31.88	$31.73	$31.73	$31.90
D. GROSS RETURNS PER PIG SOLD	$34.77	$34.77	$34.77	$34.77	$34.77	$34.77	$34.77	$34.77	$34.77	$34.77
E. RETURNS OVER VC (D-A),$/hd	-$5.57	$4.57	$7.56	$8.93	$9.59	$10.05	$10.24	$10.37	$10.39	$10.25
F. RETURNS OVER TC (D-C), $/hd	-$13.71	-$3.21	-$0.04	$1.45	$2.17	$2.67	$2.88	$3.03	$3.03	$2.87
G. NET RETURN ON INVESTMENT	-12.8%	1.8%	6.5%	8.8%	10.0%	10.8%	11.1%	11.4%	11.4%	11.1%

[a]Represents the sow-culling strategy (sows are culled after the parity number listed).

Table 3. Sensitivity of Returns over Total Costs to Various Cost Assumptions

	Return over Total Costs, $/hd									
Costs	1	2	3	4	5	6	7	8	9	10[a]
Replacement Gilt, $/hd										
$150 (-25%)	$5.39	$1.15	$3.05	$3.91	$4.30	$4.56	$4.62	$4.64	$4.55	$4.35
$200 (base)	$13.71	-$3.21	-$0.04	$1.45	$2.17	$2.67	$2.88	$3.03	$3.03	$2.87
$250 (+25%)	$22.03	-$7.57	-$3.13	-$1.02	$0.04	$0.79	$1.15	$1.42	$1.52	$1.39
Gestation/Lactation Diets, $/ton										
$100/$107 (-25%)	-$11.79	-$1.33	$1.84	$3.33	$4.07	$4.58	$4.82	$4.99	$5.02	$4.89
$134/$143 (base)	-$13.71	-$3.21	-$0.04	$1.45	$2.17	$2.67	$2.88	$3.03	$3.03	$2.87
$167/$178 (+25%)	-$15.64	-$5.09	-$1.92	-$0.44	$0.28	$0.76	$0.95	$1.08	$1.05	$0.85

[a]1 to 10 = parity prior to culling.

Table 4. Sensitivity of Returns over Total Costs to Productivity Assumptions

Conception	Return over Total Costs, $/hd									
Rate Scenario	1	2	3	4	5	6	7	8	9	10[a]
Litter size by parity relationship – "Base"										
Base	$13.71	-$3.21	-$0.04	$1.45	$2.17	$2.67	$2.88	$3.03	$3.03	$2.87
Base + 10%	$11.36	-$1.85	$0.94	$2.26	$3.04	$3.54	$3.66	$3.79	$3.63	$3.59
Base –10%	$16.84	-$5.02	-$1.51	$0.27	$1.15	$1.61	$1.77	$1.90	$1.87	$1.87
+40% at P10	$13.71	-$2.96	$0.35	$1.80	$2.67	$3.19	$3.42	$3.53	$3.54	$3.43
-40% at P10	$13.71	-$3.66	-$0.62	$0.73	$1.43	$1.79	$2.11	$2.18	$2.17	$1.94
Litter size by parity relationship – "Hypothetical"										
Base	$13.72	-$2.80	$0.50	$1.95	$2.59	$3.00	$3.12	$3.18	$3.14	$2.98
Base + 10%	$11.37	-$1.45	$1.47	$2.76	$3.45	$3.85	$3.86	$3.91	$3.71	$3.66
Base –10%	$16.85	-$4.59	-$0.95	$0.79	$1.59	$1.96	$2.03	$2.10	$2.03	$2.02
+40% at P10	$13.72	-$2.55	$0.89	$2.31	$3.08	$3.50	$3.63	$3.64	$3.60	$3.49
-40% at P10	$13.72	-$3.26	-$0.09	$1.24	$1.87	$2.14	$2.36	$2.38	$2.33	$2.11

[a]1 to 10 = parity prior to culling.

EFFECTS OF DIETARY ELECTROLYTE BALANCE ON SOW AND LITTER PERFORMANCE, BLOOD CHEMISTRY, AND URINE CHEMISTRY IN LACTATING SOWS[1]

J. M. DeRouchey, J. D. Hancock, R. H. Hines, C. A. Maloney, D. J. Lee, D. W. Dean, H. Cao, and J. S. Park

Summary

Decreasing the dietary electrolyte balance (dEB) in diets for lactating sows from 500 to 100 mEq/kg increased piglet survivability but had no effect on litter weight gain. Decreased dEB reduced pH and bacteria in the sows urine and, thus, could influence the health status of the reproductive tract.

(Key Words: Sows, Dietary Electrolyte Balance, Acid-Base Balance.)

Introduction

Dietary electrolyte balance is calculated as the sum of Na and K minus Cl and is expressed in mEq/kg of diet. The manipulation of dietary electrolyte balance (dEB) to enhance lactation and reproductive performance in dairy cattle and laying hens is not a new concept. However, the effects of dEB on reproduction and lactation in sows have not been elucidated. Thus, our objective for the experiments reported herein was to determine the impact of dEB on performance of lactating sows and their litters.

Procedures

Treatment Determination. On d 109 of gestation, 30 sows (Line C 22; PIC, Franklin, KY) were assigned to lactation treatments and moved to a farrowing facility. Diets were corn-soybean meal-based (Table 1) and fed in meal form. The dEB treatments of -150, -100, 0, 100, and 200 were selected based on previous research in growing pigs. The sows were allowed ad libitum consumption of feed (four feedings per d) and water (via a nipple waterer). Orts were collected and weighed on d 7 and at weaning to allow calculation of ADFI. Litter size was standardized within 24 h postfarrowing, and all sows had at least 10 pigs after cross-fostering. Sow and piglet weights were recorded at farrowing and weaning.

Lactation Experiment. On d 110 of gestation, 153 sows (Line C 22; PIC, Franklin, KY) were assigned to lactation treatments and moved to a farrowing facility. There were six farrowing groups, with parity ranging from 1 to 4. We were careful to ensure that parity number was comparable among all treatments. Treatments were corn-soybean meal-based diets (Table 2) with dEBs of 0, 100, 200, 350, and 500 mEq/kg. All diets were formulated to constant Ca, P, and K concentrations, and Cl and Na were changed to achieve the desired dEB treatments. The lowest dEB (0) was achieved by mixing 1.08% $CaCl_2$ and 1.8% HCl (6 N) into the diet. The dEB treatment of 100 had 1.0% $CaCl_2$. The diets with dEBs of 200, 350, and 500 mEq/kg required additions of .08, 1.5, and 2.5% sodium bicarbonate, respectively. A typical lactation diet that is formulated to a similar nutrient profile as used in this experiment would contain a dEB of approximately 185 mEq/kg. The sows were allowed ad libitum consumption of feed (four feedings per d) and water (via a nipple waterer). Each farrowing crate was equipped with a water meter, so water disappearance could be determined. Orts were collected and weighed on

[1]Appreciation is extended to Church and Dwight, Princeton, NJ, for financial assistance with this project.

d 10 and at weaning to allow calculation of ADFI.

The sows were weighed and scanned ultrasonically at the first rib, last rib, last lumbar vertebra, and off midline at the last rib (both sides) to determine weight and backfat at farrowing, d 10, and at weaning. Litter size was standardized within 24 h post-farrowing, and piglet weights were recorded at farrowing, d 10, and weaning. All sows used in the experiment had at least 10 pigs after cross fostering.

Between d 10 and 12 of lactation, approximately 75 mL of urine (midstream) was collected at 6:00 a.m. from each sow. The samples immediately were analyzed for pH and total bacteria. At d 10 to 12 of lactation (2 h after the first morning feeding), the sows were restrained with a nose snare and given .5 mL of oxytocin (via ear vein) to enhance milk letdown. A sample of about 100 mL of milk was collected from the first three productive mammary glands on each side. Milk lactose, fat, protein, and pH were determined. Finally, blood samples were collected from the sows; placed on ice; and within 20 min, were analyzed for pH, pCO_2, pO_2, Na, K, Cl, and Ca.

Statistical analyses were performed with sow as the experimental unit. Polynomial regression was used to describe the shape of the response to changes in dEB. Lactation length, parity, and initial litter size after cross-fostering were used as covariates for analyses of weaning weight; litter weight gain; survivability of the pigs; ADFI, backfat, and BW changes; percentage return to estrus; and days to estrus for the sows. Parity and lactation length were used as covariates for number born alive in the subsequent litter. Also, parity was used as a covariate for analyses of milk chemistry.

Results and Discussion

Treatment Determination. At d 7, ADFIs were similar (10 to 11 lb/d) among sows fed the dEB treatments of 0, 100, and 200 mEq/kg. However, sows fed the lowest dEB treatments (-100 and -150 mEq/kg) had an ADFI of only of 5.3 lb/d (linear effect, P<.03). Thus, those two treatments were dropped from the experiment. The other sows were continued on their treatment diets until weaning at d 21.

Sow weight change (P>.39), litter weight gain (P>.28), and ADFI (P>.45) were not affected by the dEB treatments of 0, 100, and 200 mEq/kg. Thus, we concluded from this pilot project that to avoid depressing feed intake, the lowest dEB to use for the larger-scale lactation experiment should be 0 mEq/kg.

Lactation Experiment. Sow weight and backfat loss during lactation were not affected (P>.11) by dEB (Table 3). Also, ADFI and water usage were not affected by dEB at d 10 (P > .06) and overall (P>.17).

Number of pigs (P<.04) and survivability (P<.05) of the piglets during the first 10 d of lactation increased as dEB was decreased. Similarly, number weaned (P<.01) and overall survivability (P<.02) increased with decreased dEB. The greater survivability could have been a function of greater milk output and(or) health status of the pigs as dEB was decreased. This hypothesis was supported by the slight numerical increase in litter weight gain with decreased dEB, but differences were not significant at d 10 (P>.15) or overall (P>.41). Finally, percentage of sows returning to estrus (P>.41), d to estrus (P>.15), and number born in the subsequent litter (P>.39) were not affected by dEB of the lactating diet.

Milk pH (P>.13), fat (P>.32), lactose (P>.36), and CP (P>.44) were not altered by dEB (Table 4). Thus, it seems unlikely that the composition and, thus, nutritional value of sow's milk can be manipulated by changing the dEB of the diet. However, blood pH (quadratic effect, P<.001), pCO_2 (linear effect, P<.001), and bicarbonate (quartic effect, P<.003) were decreased as dEB was decreased showing a direct metabolic response to differences in diet acidity.

As for blood electrolytes, Na concentrations decreased (quartic effect, P<.07) and K and Cl concentrations increased (quadratic

effect, P<.04) with decreased dEB. Both ionized (quadratic effect, P<.001) and normalized (linear effect, P<.005) Ca in blood were increased with decreased dEB. This indicates greater bone mobilization with a more acidic diet. In dairy cattle, early lactation diets are formulated to low dEB to increase Ca concentrations in the blood, which helps suppress the incidence of milk fever. However, milk fever is not a known concern in lactating sows, and our data indicate no advantage in lactation performance from increased circulating concentrations of Ca.

The pH of urine (quartic effect, P<.001) and total bacterial counts were decreased with decreased dEB (linear effects, P<.03). Urinary tract disease is caused by bacteria in the reproductive tract. and acidic diets are used extensively in the pet food industry to prevent this disease. Thus, it seems plausible that acidic diets could be used to decrease urinary tract disease in afflicted sow herds.

In summary, the acid-base balance in lactating sows was influenced by dietary electrolyte balance. Decreasing dietary electrolyte balance below that of a simple-corn-soybean meal-based diet decreased urine pH and bacterial counts and increased piglet survivability and the number of pigs weaned.

Table 1. Compositions of Diets for Treatment Determination[a]

	Electrolyte Balance, mEq/kg[b]				
Item	-150	-100	0	100	200
Ingredient, %					
Corn	59.93	60.51	61.80	62.58	62.78
Soybean meal (46.5% CP)	27.10	27.08	27.03	26.94	26.88
Corn gluten meal	3.34	3.27	3.11	3.03	2.95
Soy oil	3.00	3.00	3.00	3.00	3.00
Sodium bicarbonate	---	---	---	---	.04
Calcium chloride	1.98	1.98	1.98	1.00	---
HCl (6 *N*)	1.54	1.05	---	---	---
H_3PO_4	1.86	1.86	1.84	---	---
Monocalcium phosphate	---	---	---	2.13	2.12
Limestone	---	---	---	.11	1.24
Salt	.50	.50	.50	.50	.50
Vitamin premix	.50	.50	.50	.50	.50
Trace mineral premix	.15	.15	.15	.15	.15
Antibiotic[c]	.10	.10	.10	.10	.10

[a]Diets were formulated to 1.0% lysine, 1.0% valine, .95% Ca, and .8% P.

[b]Calculated as mEq/kg of Na + K – Cl.

[c]Provided 100 g of chlortetracycline per ton of complete diet.

Table 2. Compositions of Diets for Lactation Experiment[a]

	Electrolyte Balance, mEq/kg				
Item	0	100	200	350	500
Ingredient, %					
Corn	59.33	59.33	59.33	59.33	59.33
Soybean meal (46.5% CP)	27.13	27.13	27.13	27.13	27.13
Corn gluten meal	3.42	3.42	3.42	3.42	3.41
Soy oil	3.00	3.00	3.00	3.00	3.00
Sodium bicarbonate	---	---	.04	1.29	2.54
Calcium chloride	1.06	1.00	---	---	---
HCl (6 *N*)	1.80	---	---	---	---
Cellulose[b]	.90	2.67	2.50	1.25	---
Monocalcium phosphate	2.11	2.11	2.11	2.11	2.11
Limestone	---	.09	1.22	1.22	1.22
Salt	.50	.50	.50	.50	.50
Vitamin premix	.50	.50	.50	.50	.50
Trace mineral premix	.15	.15	.15	.15	.15
Antibiotic[c]	.10	.10	.10	.10	.10
Analyzed composition, %					
DM	88.5	89.0	89.0	88.9	88.9
Ash	5.0	5.5	5.3	5.7	5.8
CP	19.6	19.6	19.8	19.6	19.6
Ether extract	5.2	5.1	5.2	5.4	5.3
pH	4.01	5.21	6.12	6.82	6.98
Ca	.95	.97	.93	.94	.96
P	.80	.78	.78	.81	.83
Na	.21	.18	.22	.56	.85
K	.78	.76	.77	.75	.78
Cl	.97	.59	.32	.30	.31
Electrolyte balance, mEq/kg[d]	15	107	203	351	482

[a]Diets were formulated to 1.0% lysine, 1.0% valine, .95% Ca, and .8% P.

[b]Solka floc (Fiber Sales, Urbana, OH).

[c]Provided 100 g of chlortetracycline per ton of complete diet.

[d]Calculated as mEq/kg of Na + K – Cl from analyzed values.

Table 3. Effects of Dietary Electrolyte Balance on Performance of Sows and Litters[a]

	Electrolyte Balance, mEq/kg						Probability			
Item	0	100	200	350	500	SE	Linear	Quadratic	Cubic	Quartic
No. of observations	27	33	34	28	31					
Mean parity	2.1	2.4	2.2	2.1	2.2	.2	---[d]	---	---	---
Mean lactation length, d	20.6	21.2	21.0	21.0	20.9	.3	---	---	---	---
Sow BW postfarrowing, lb	478.3	478.0	488.0	493.7	485.8	3.6	---	---	---	---
Fat depth postfarrowing, in	.63	.67	.69	.69	.44	.7	---	.15	---	---
Initial pigs/litter	11.4	11.3	11.4	11.4	11.2	.2	---	---	—	---
Initial litter BW, lb	37.3	39.2	38.8	39.2	38.8	.5	---	---	---	---
d 10									---	
BW change, lb	-17.2	-9.0	-9.7	-16.5	-18.5	1.6	---	.11	---	---
Fat change, in	-.01	-.01	-.01	-.01	-.01	.01	---	---	.06	---
ADFI, lb	9.7	11.2	10.6	10.4	10.6	.2	---	---	---	---
Water usage, gal/d	14.0	13.2	13.3	11.6	14.2	5.4	.04	---	---	---
Pigs/litter	10.7	10.5	10.5	10.3	10.3	.2	.05	---	---	---
Survivability, %	94.7	93.0	92.9	91.5	91.2	1.3	---	---	---	---
Litter wt, lb	79.4	78.1	80.0	78.3	76.3	1.1	.15	---	---	---
Litter wt gain, lb	42.1	38.9	41.2	39.1	37.5	.9		---		---
Weaning							---		---	
BW change, lb	-31.3	-24.5	-23.4	-32.2	-36.4	2.1	.14	.11	---	---
Fat change, in	-.02	-.01	-.01	-.01	-.02	.01	---	---	---	---
ADFI, lb	11.4	12.3	12.7	11.9	12.3	.2	—	---	---	---
Water usage, gal/d	12.9	12.6	12.1	11.8	14.6	5.0	.01	---	---	---
Pigs/litter	10.5	10.3	10.1	10.0	9.9	.2	.02	---	---	---
Survivability, %	92.9	91.1	89.3	88.6	87.8	1.6	---	---	---	---
Litter wt, lb	135.0	133.4	134.1	133.2	131.9	1.9	---	---	---	---
Litter wt gain, lb	97.7	94.2	95.3	94.0	93.1	1.7	---	---	---	---
Return to estrus, %[b]	91.6	91.4	94.2	96.1	93.2	4.4	---	---	.15	---
Days to estrus[c]	4.6	5.5	4.9	4.3	4.3	.4		---		---
Subsequent no.							---		--	
Born alive	11.1	10.3	11.2	10.7	11.1	.3		---		---

[a]A total of 153 sows.
[b]Percentage sows returning to estrus within 30 d of weaning.
[c]For sows returning to estrus within 30 d of weaning.
[d]Dashes indicate P>.15.

Table 4. Effects of Dietary Electrolyte Balance on Milk, Blood, and Urine Chemistry in Lactating Sows[a]

	Electrolyte Balance, mEq/kg						Probability			
Item	0	100	200	350	500	SE	Linear	Quadratic	Cubic	Quartic
Milk Composition										
pH[b]	6.97	6.96	6.99	7.03	6.99	.02	---[d]	---	.13	---
Fat, %	6.0	6.1	6.3	6.2	6.3	.2	---	---	---	---
Lactose, %	5.5	5.5	5.4	5.5	5.5	.1	---	---	---	---
CP, %	4.6	4.7	4.7	4.7	4.7	.1		---	---	---
Whole blood							.001			
pH[b]	7.33	7.36	7.39	7.41	7.43	.01	.001	.001	---	---
pCO_2, mmHg	46.3	46.5	49.0	49.9	50.8	.7	—	---	---	.15
pO_2, mmHg	43.6	42.9	44.8	43.4	40.1	1.5	.001	.12	---	---
HCO_3^-, mmol/L	19.0	21.4	25.1	25.5	28.8	.3	—	.001	---	.003
Na^+, mmol/L	145.0	145.5	144.7	145.0	145.3	.3	.007	—	---	.07
K^+, mmol/L	5.0	4.9	4.7	4.7	4.7	.1	.001	.04	---	---
Cl^-, mmol/L	109.8	108.0	104.0	102.4	101.4	.3	.001	.001	---	.007
Electrolyte balance[c]	40.2	42.4	45.4	47.3	48.6	.4		.002	---	.13
Ca^{++}, mg/dL							.001		---	
Ionized	5.5	5.3	5.2	5.1	5.0	.03	.005	.001		---
Normalized	5.3	5.3	5.2	5.2	5.2	.03		---	---	---
Urine							.001		---	
pH[b]	4.87	5.01	6.64	7.00	7.70	.2	.03	.001	---	.001
Bacteria, log	3.86	4.00	4.15	4.27	4.19	.12		---		---

[a]A total of 153 sows.

[b]Converted to $[H^+]$ before statistical analysis was conducted.

[c]Calculated as Na + K – Cl from analyzed values.

[d]Dashes indicate P > .15.

EVALUATION OF TWO PROSTAGLANDIN PRODUCTS IN PREGNANT SOWS FOR INITIATION OF LUTEOLYSIS[1]

E. I. Evans[2], S. S. Dritz[3], J. S. Stevenson, and D. L. Davis

Summary

We used 66 pregnant sows to compare serum progesterone concentrations following a single injection of either saline or one of two prostaglandin F2α products approved for use in swine. Pregnant sows in a commercial swine farm were assigned to one of the three groups in a completely randomized design balanced across treatment for parity and day of gestation. Each sow received a single intramuscular dose (2 mL) on d 111, 112, or 113 of gestation. Mean serum progesterone concentrations were decreased significantly at 6 and 12 hours after dose administration of both prostaglandin products. However, these effects did not differ. Serum progesterone concentrations did not decrease significantly at any time in the control group. This indicates that regression of corpora lutea was initiated at the same time by both prostaglandin products.

(Key Words: Pregnant Sows, Prostaglandins, Luteolysis.)

Introduction

This study was conducted to compare progesterone blood levels in pregnant sows following a single injection of either a generic (Prostamate™, Phoenix Scientific, Inc.) or originally marketed (Lutalyse®, Pharmacia & Upjohn Company) prostaglandin product (dinoprost tromethamine) approved for use in swine. This prostaglandin is used commonly on swine farms to induce farrowing.

Procedures

The study was conducted on a commercial swine operation (Global Ventures, Inc.) in Pipestone, Minnesota. Sows were housed individually in environmentally controlled farrowing facilities. Water was provided ad libitum, and feed was offered at least three times daily according to the farm's standard procedures. On the day prior to dosing, animal identification, farrowing date, and parity were confirmed, and animals were assigned randomly to treatment groups balanced across day of gestation and parity. Sows that had already farrowed or were off feed were excluded from the study. Sixty-six pregnant sows were assigned randomly to one of three dose groups. Identity of the test materials (saline, ProstaMate™ and Lutalyse®) was not revealed to KSU personnel or farm staff until after the trial had concluded. Each sow received a single intramuscular dose (2 mL) of her assigned product on d 111, 112, or 113 (Day 0 was onset of estrus) of gestation. The KSU staff administering the injections knew only the group designation (1, 2, or 3). The farrowing supervisor observed all gilts and sows at least once daily for general health

[1]Appreciation is expressed to Michelle Jones, Bradley Petersen, and Luke Minion of Global Ventures for technical assistance and use of animals and facilities and Betty Hensley for technical assistance. Appreciation also is expressed to Phoenix Scientific for financial support.

[2]Midwest Research Institute, Kansas City, MO.

[3]Food Animal Health and Management Center.

and appearance from 2 days before to 5 days after administration of the test materials.

Blood samples were collected from each animal via the anterior vena cava or jugular vein prior to dosing and at approximately 6 and 12 hours after dose administration. Concentrations of serum progesterone were analyzed using a radioimmunoassay technique. The data were analyzed using a repeated measures mixed effects model in SAS® The fixed effects included treatment (1, 2, or 3); time period after treatment administration (0, 6, or 12 hours); and the interaction between treatment and time period. The sow within treatment term was specified as a random effect. The means were reported as least square means using a Satterthwaite correction for the degrees of freedom.

Results and Discussion

The farrowing supervisor noted no abnormal behavior in any of the study animals. She noted that animals in Groups 2 and 3 showed more agitation along with chewing and nesting behaviors prior to farrowing, although she did not document any differences between those two groups. Two days after dosing, she accurately guessed that animals in Group 1 received the saline, because they did not exhibit these behaviors and many had not yet farrowed.

Mean serum progesterone concentrations were decreased significantly at 6 and 12 hours after administration of both prostaglandin products (Table 1). However, no statistically significant differences occurred between the effects of the two products. Mean serum progesterone concentrations did not decrease significantly at any time in the control (saline) group. The serum concentrations of progesterone in this study indicate that luteolysis or regression of the copora lutea of pregnancy was initiated at the same time for both products. Because this is the initial mechanism leading to farrowing after prostaglandin injection, the two products should be equally efficacious for induction of farrowing.

Table 1. Effects of Prostaglandin Products on Serum Progesterone Concentrations in Pregnant Sows (ng/mL)[a]

Time (hr)	Group 1 (saline)	Group 2 (Prostamate™)	Group 3 (Lutalyse®)
0	479	4.58^{x}	4.46^{x}
6	451	4.01^{y}	3.92^{y}
12	4.51^{b}	2.96^{c,z}	2.46^{c,z}
SEM	±0.21	±0.21	±0.22
N	22	23	21

[a]Time by treatment interaction (P<0.001).

[b,c]Means within rows with unlike superscripts are significantly different (P<0.05).

[x,y,z]Means within columns with unlike superscripts are significantly different (P<0.05).

N=number of sows dosed.

THE OPTIMUM ISOLEUCINE:LYSINE RATIO IN STARTER DIETS TO MAXIMIZE GROWTH PERFORMANCE OF THE EARLY-WEANED PIG[1]

B. W. James, R. D. Goodband, M. D. Tokach, J. L. Nelssen, and J. M. DeRouchey

Summary

A total of 360 weanling pigs (initially 12.3 lb BW and approximately 18 d of age) was used in a 14-d growth assay to determine the optimal isoleucine:lysine ratio to maximize growth performance. The 12 experimental treatments consisted of either 1.00 or 1.26% apparent digestible lysine with isoleucine concentrations of 45, 50, 55, 60, or 65% of lysine. Two positive control diets were used with 1.10 and 1.39% apparent digestible lysine and 45% isoleucine:lysine to ensure that lysine was not the first limiting amino acid in the basal diets. The results of this experiment indicate that the optimal apparent digestible isoleucine:lysine ratio for the SEW pig is between 50 and 55% of apparent digestible lysine.

(Key Words: Isoleucine, Lysine, Weanling Pigs.)

Introduction

Nutrient profiles of ingredients and amino acid requirements vary between the 1988 and 1998 NRC publications. These changes have resulted in an increase in the isoleucine requirement for the early-weaned pig. The current NRC requirements of apparent digestible lysine and isoleucine for a 6 to 11 lb pig are 1.26% and .69% of the diet, respectively, suggesting an apparent digestible isoleucine:lysine ratio of 55%. Recent changes in starter diets have resulted in increased levels of blood meal or blood cells being used as highly digestible protein sources for weanling pigs. However, these products contain a lower concentration of isoleucine than other protein sources. The objective of this experiment was to determine the appropriate apparent digestible isoleucine:lysine ratio necessary to optimize performance of the SEW pig.

Procedures

Three hundred and sixty weanling pigs (initially 12.3 lb BW and approximately 18 d of age, PIC C22 × 327) were used in a 14-d growth assay. Pigs were blocked by initial weight and allotted randomly to each of the 12 dietary treatments. Each treatment had six replications (pens) and five pigs per pen.

Corn, soybean meal, spray-dried plasma, blood meal, fish meal, and spray-dried whey were analyzed for complete amino acid profiles prior to diet formulation based on apparent digestible amino acid composition of those ingredients. The 12 experimental treatments consisted of two basal diets (Table 1) containing 1.00 and 1.26% apparent digestible lysine with .45 and .57% isoleucine, respectively, and all other amino acids except isoleucine (Table 2) formulated to 110 % of the recommended NRC requirements. Crystalline isoleucine then was added to each of the basal diets to meet the desired level of each treatment (50, 55, 60, and 65% of lysine). Lysine was added to two positive controls to provide 1.10 and 1.39% apparent digestible lysine and ensure that lysine was not the first limiting amino acid. All diets were fed in pellet form.

[1]Appreciation is expressed to Nutri-Quest, Chesterfield, MO, for providing the crystalline amino acids used in this experiment.

Pigs were housed in an environmentally controlled nursery. Temperature was maintained at 90° F for the first week and reduced to 85°F for the second week. Each pen (4 × 4 ft) contained a stainless steel self-feeder and one nipple waterer to allow ad libitum consumption of feed and water.

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

	Apparent Digestible Lysine, %	
Ingredient	1.00	1.26
Corn	33.90	42.69
Cornstarch[b]	14.00	.25
Lactose	12.66	10.50
Dried whey	12.00	15.00
Soybean meal (46.5% CP)	6.04	7.92
Choice white grease	5.00	5.00
Spray-dried blood plasma	4.40	5.50
Select menhaden fish meal	4.00	5.00
Spray-dried blood cells	3.20	4.00
Monocalcium phosphate	2.59	1.56
Medicationc	1.00	1.00
Zinc oxide	.37	.37
Limestone	—	.33
Vitamin premix	.25	.25
Salt	.20	.20
Trace mineral premix	.15	.15
DL-Methionine	.08	.09
L-threonine	.07	.08
Sow add pack	.05	.05
Cystine	.02	.03
L-Isoleucine	.02	.03

[a]Diets were formualted to 45% isoleucine:lysine with all other amino acids at 110% of NRC requirements.

[b]L-Isoleucine replaced cornstarch in the 1.00 and 1.26% apparent digestible lysine basal diets to provide .45, .50, .55, .60, and .65% apparent digestible isoleucine and .567, .63, .693, .756, and .819% apparent digestible isoleucine, respectively. This provided apparent digestible isoleucine:lysine ratios of 45, 50, 55, 60, and 65% at both lysine levels.

[c]Provided 50 g/ton carbadox.

Experimental treatment diets were fed from d 0 to 14 postweaning. Pigs were weighed and feed disappearance measured on d 7 and 14 of the experiment to determine ADG, ADFI, and F/G. Blood samples were obtained on d 10 from two randomly selected pigs in each pen. Feeders were removed 3 hours prior to blood collection. Plasma urea nitrogen (PUN) was determined on each sample. Plasma from pigs in the same pen were pooled and analyzed for amino acid profiles.

Data were analyzed in a randomized complete block design using the general linear model (GLM) procedures of SAS with pen as the experimental unit. Linear and quadratic polynomial contrasts were performed to determine the effects of increasing levels of dietary isoleucine.

Results and Discussion

No isoleucine × lysine interactions were observed (P>.47) from d 0 to 7 (Table 3). Increasing the apparent digestible isoleucine:lysine ratio improved ADG, ADFI, and F/G (linear and quadratic, P<.01) from d 0 to 7. The greatest response occurred as the isoleucine:lysine ratio increased from 45 to 50%, and a smaller incremental improvement occurred as the ratio increased from 50 to 55%. Pigs fed the diet containing 1.26% apparent digestible lysine had better ADG than pigs fed 1.00% apparent digestible lysine (P<.03). From d 0 to 7, growth performance of pigs fed the positive control diets was not different (P>.05) than that of pigs fed the negative control diets. This confirms that isoleucine was first limiting during this phase.

From d 7 to 14, lysine × isoleucine interactions were observed for ADG and ADFI. At either dietary lysine level, increasing apparent digestible isoleucine improved (linear and quadratic, P<.01) ADG, ADFI, and F/G. However, ADG appeared to be maximized at 55% isoleucine in diets containing 1.00% apparent digestible lysine, whereas pigs fed 1.26% apparent digestible lysine maximized ADG at approximately 50% isoleucine. Pigs fed the

diet containing 1.26% apparent digestible lysine had better (P<.01) ADG and F/G compared to pigs fed 1.00% apparent digestible lysine. Pigs fed the positive control diet containing 1.39% apparent digestible lysine had better growth performance (P<.06) from d 7 to 14 compared to pigs fed 1.26% apparent digestible lysine. This suggests that lysine was becoming colimiting in the diet with isoleucine.

From d 0 to 14, an isoleucine × lysine interaction (P<.06) was observed for ADFI. Pigs fed 1.00% apparent digestible lysine obtained optimal feed intake at 55% isoleucine; however, those fed 1.26% apparent digestible lysine achieved maximum feed intake at 50% isoleucine. The greatest response to increasing levels of isoleucine occurred as the apparent digestible isoleucine:lysine ratio increased from 45 to 50%, and further numeric improvements occurred as the ratio increased from 50 to 55% at the 1.00% apparent digestible level. Feeding 1.26% apparent digestible lysine improved (P<.02) ADG and F/G from d 0 to 14. Overall, the positive control fed 1.39% apparent digestible lysine had better (P<.02) ADG and F/G compared to pigs fed 1.26% apparent digestible lysine. This suggests that lysine was colimiting with isoleucine in the 1.26% apparent digestible lysine diet.

The plasma isoleucine concentration increased (linear, P<.01) with increasing dietary isoleucine (Table 4). The greatest response occurred as the isoleucine:lysine ratio increased from 50 to 55%. The plasma lysine concentration tended to decrease (quadratic, P<.07) as the ratio of isoleucine: lysine approached the pigs' requirement. This suggests that lysine was used more efficiently when the isoleucine:lysine ratio was not deficient or in excess of the level needed to obtain optimal growth. The greatest response with 1.00% apparent digestible lysine occurred as the isoleucine:lysine ratio increased from 50 to 55%; however, the greatest response at 1.26% lysine occurred as the ratio increased from 45 to 50%.

We then used break-point analysis to determine the isoleucine requirement. The broken-line method, which predicts requirements for the average animal in the population, predicted requirements of approximately 55% isoleucine:lysine at 1.00% apparent digestible lysine and approximately 50% isoleucine:lysine at 1.26% apparent digestible lysine to achieve optimal growth performance (Table 5). Calculation of the daily isoleucine intake requirement, using NRC 1998 equations based on actual BW and performance of all pigs in this experiment, estimated average requirements of 1.2 g/d isoleucine from d 0 to 7 and 2.3 g/d from d 7 to 14. The calculated isoleucine intake requirements that correlated with 55% isoleucine:lysine at 1.00% apparent digestible lysine were 1.2 g/d for d 0 to 7 and 2.5 g/d for d 7 to 14. The calculated requirements with 50% isoleucine:lysine at 1.26% apparent digestible lysine were 1.4 g/d for d 0 to 7 and 2.5 g/d for d 7 to 14.

Based on the results of this experiment, the optimal apparent digestible isoleucine: lysine ratio for the 15 lb SEW pig is between 50 to 55% of apparent digestible lysine.

Table 2. Calculated Composition of Control Diets[a,b], %

	Apparent Digestible Lysine, %			
	1.00		1.26	
Item, %	Total	Digestible	Total	Digestible
CP (N × 6.25)	16.12	—	20.35	—
Threonine	.81	.66	1.02	.83
Valine	.93	.79	1.17	.99
Methionine	.34	.30	.42	.37
Isoleucine	.53	.45	.67	.57
Leucine	1.61	1.40	2.02	1.77
Tyrosine	—	—	—	—
Phenylalanine	.83	.71	1.04	.90
Histidine	.56	.50	.71	.63
Lysine	1.17	1.00	1.47	1.26
Arginine	.85	.75	1.07	.95
Tryptophan	.25	.21	.32	.27
Ca, %	.90	—	.90	—
P, %	.88	—	.80	—

[a]Values were calculated from analyzed composition of corn, soybean meal, spray-dried plasma, blood meal, menhaden fish meal, and spray-dried whey.

[b]All amino acids in the positive control diets were the same with the exception of increased levels of lysine.

Table 3. Effects of Isoleucine:Lysine Ratio on Growth Performance of the Early-Weaned Pig

	Apparent Digestible Lysine, %																	
	1.00					1.26					1.10	1.39						
	Isoleucine, % of Lysine													Probability (P<)				
Item	45	50	55	60	65	45	50	55	60	65	45	45	SEM	Iso*Lys	Lys	Iso	Linear	Quad
Day 0 to 7																		
ADG, lb	0.17	0.26	0.32	0.33	0.30	0.19	0.35	0.35	0.34	0.37	0.16	0.23	0.02	0.62	0.03	0.01	0.01	0.01
ADFI, lb	0.26	0.31	0.35	0.39	0.35	0.27	0.39	0.38	0.35	0.37	0.27	0.27	0.02	0.47	0.27	0.01	0.01	0.01
F/G	1.67	1.32	1.10	1.20	1.17	1.49	1.13	1.08	1.07	1.07	1.51	1.22	0.10	0.97	0.15	0.01	0.01	0.01
Day 7 to 14																		
ADG, lb	0.38	0.50	0.64	0.63	0.58	0.40	0.71	0.64	0.75	0.65	0.34	0.55[a]	0.02	0.04	0.01	0.01	0.01	0.01
ADFI, lb	0.52	0.64	0.79	0.78	0.78	0.49	0.79	0.73	0.81	0.70	0.52	0.58[b]	0.02	0.01	0.87	0.01	0.01	0.01
F/G	1.39	1.27	1.23	1.23	1.34	1.27	1.12	1.14	1.08	1.08	1.46	1.06[a]	0.03	0.29	0.01	0.01	0.01	0.01
Day 0 to 14																		
ADG, lb	0.27	0.38	0.48	0.48	0.44	0.29	0.53	0.50	0.54	0.51	0.25	0.39[a]	0.02	0.12	0.02	0.01	0.01	0.01
ADFI, lb	0.39	0.48	0.57	0.58	0.56	0.38	0.59	0.56	0.58	0.54	0.39	0.43	0.02	0.06	0.47	0.01	0.01	0.01
F/G	1.45	1.27	1.17	1.21	1.28	1.33	1.12	1.12	1.08	1.06	1.44	1.10[a]	0.03	0.48	0.01	0.01	0.01	0.01
Day 10																		
PUN, mg/dL	3.74	2.82	3.44	2.49	2.19	5.19	4.32	5.76	4.88	3.31	2.87	6.61[a]	0.51	0.64	0.01	0.01	0.01	0.14

Initial BW, 12.3 lb.

[a]Contrast vs 45% Iso at 1.26% Lysine (P<.02).

[b]Contrast vs 45% Iso at 1.26% Lysine (P<.06).

Table 4. Effects of Isoleucine:Lysine Ratio on Plasma Amino Acid Profile of the Early-Weaned Pig

	Apparent Digestible Lysine, %																	
	1.00					1.26					1.10	1.39						
	Isoleucine, % of Lysine													Probability (P<)				
Item	45	50	55	60	65	45	50	55	60	65	45	45	SEM	Iso*Lys	Lys	Iso	Linear	Quad
Threonine	264	270	282	335	273	237	256	291	300	364	253	397[a]	31.3	0.38	0.82	0.18	0.02	0.85
Valine	307	310	290	326	281	297	311	328	316	308	240[b]	329	19.4	0.69	0.48	0.77	0.92	0.31
Methionine	51	52	43	40	43	61	51	55	53	46	37[b]	42[a]	4.5	0.47	0.01	0.13	0.01	0.66
Isoleucine	28	29	53	74	76	42	40	69	77	105	32	30	8.4	0.73	0.01	0.01	0.01	0.41
Leucine	216	204	195	211	182	205	222	218	213	202	158[b]	208	13.6	0.72	0.27	0.62	0.26	0.41
Tyrosine	92	95	81	83	80	100	87	92	80	96	75	121	7.6	0.53	0.36	0.41	0.14	0.28
Phenylalanine	79	85	82	77	75	83	73	87	77	77	64	79	6.0	0.57	0.95	0.65	0.35	0.54
Tryptophan	36	43	34	36	39	39	35	34	32	42	36	50[a]	2.7	0.21	0.46	0.09	0.93	0.05
Lysine	115	129	73	90	74	115	87	90	79	134	194[b]	262[a]	17.0	0.06	0.65	0.17	0.21	0.07
Histidine	101	95	85	83	75	101	86	82	80	74	72[b]	72[a]	6.6	0.97	0.47	0.01	0.01	0.50
Arginine	64	72	67	68	70	77	75	91	92	110	63	89	10.3	0.56	0.01	0.48	0.07	0.78

[a]Contrast vs 45% Iso at 1.26% Lysine (P<.05).

[b]Contrast vs 45% Iso at 1.00% Lysine (P<.05).

Table 5. Predicted Isoleucine:Lysine Ratio from Break-Point Analysis

	Apparent Digestible Lysine, %			
	1.00		1.26	
Item	Two-Slope[a]	One-Slope[b]	Two-Slope[a]	One-Slope[b]
Day 0 to 7				
ADG, lb	53.83	53.15	49.59	50.10
ADFI, lb	60.47	57.04	49.72	49.14
F/G	53.03	52.33	50.66	50.79
Day 7 to 14				
ADG, lb	56.20	54.86	49.56	49.29
ADFI, lb	55.00	55.00	49.89	49.16
F/G	53.24	50.14	48.17	50.67
Day 0 to 14				
ADG, lb	54.87	53.94	49.67	49.75
ADFI, lb	56.36	55.00	49.89	49.37
F/G	53.40	51.39	49.26	50.79
Plasma amino acids				
Isoleucine	42.32	61.76	48.73	—
Lysine	47.42	55.63	53.00	47.84

[a]$Y = L + U(R–X_{LR}) + V(X_{GR}–R)$, where L = the ordinate of the break point in the curve, R = the abscissa of the break point in the curve (the requirement estimate); X_{LR} = a value of X less than R; X_{GR} = a value of X greater than R; U = the slope of the line for X less than R; V = the slope of the line for X greater than R.

[b]$Y = L + U(R–X_{LR})$, where L = the ordinate of the break point in the curve, R = the abscissa of the break point in the curve (the reqirement estimate); X_{LR} = a value of X less than R; U = the slope of the line for X less than R.

EFFECTS OF DIETARY L-CARNITINE ON GROWTH PERFORMANCE OF NURSERY PIGS

D. E. Real, M. J. Rincker, M. U. Steidinger, J. L. Nelssen, S. D. Carter[1], R. D. Goodband, M. D. Tokach, S. S. Dritz[2], and K. Q. Owen[3]

Summary

Four experiments were conducted to evaluate the effects of added dietary L-carnitine on growth performance of nursery pigs. Pigs were fed a control diet containing no added L-carnitine or the control diet with 25, 50, 75, or 100 ppm of added L-carnitine (25, 50, or 100 ppm in Exp. 4). In Exps. 1, 2, and 3 for the overall study, ADG and F/G improved with increasing dietary L-carnitine. In Exp. 4, pigs fed increasing L-carnitine had improved ADG from d 0 to 3 and d 10 to 24. Increasing added carnitine improved F/G from d 10 to 24 and for the overall study. The results suggest that 25 to 50 ppm of added L-carnitine can improve ADG and F/G in nursery pigs. The largest response in pig growth performance was found when carnitine was supplemented to the phase II diet.

(Key Words: Carnitine, Nursery Pigs, B-Vitamin.)

Introduction

Carnitine, a B-vitamin-like compound naturally occurring in the body, functions to transport long chain fatty acids into the mitochondria. Increasing the amount of dietary carnitine might improve that transport, resulting in better energy utilization by the pig. Previous studies have observed decreased lipid deposition in weanling pigs fed up to 1,000 ppm of added L-carnitine. If these improvements in leanness could be observed at lower concentrations, L-carnitine additions would be justified economically. Therefore, the objective of these experiments was to determine if adding 25 to 100 ppm of L-carnitine to nursery pig diets would improve growth performance.

Procedures

In Exp. 1, a 34-d growth assay, 190 (initially 12.4 lb and 16 ± 2 d of age) pigs were housed in an environmentally regulated nursery at the Kansas State University Segregated Early-Weaning Facility. Pigs were provided ad libitum access to feed and water and housed in 4 × 4-ft pens. Pigs were blocked based on initial weight in a randomized complete block design. There were eight pens (replications) per treatment and each pen contained four or five pigs.

The trial was divided into four phases based on diet complexity (Table 1). Four diets were fed from d 0 to 7, d 7 to 14, d 14 to 24, and d 24 to 34. Pigs were weighed and feed disappearance was determined at the end of each phase to determine ADG, ADFI, and F/G

In Exps. 2 and 3, 240 pigs (10.8 lb and 12 ± 2 d of age) were used in 38-d growth trials. Pigs were blocked by weight and allotted to one of five dietary treatments. There were eight pigs per pen and six pens per treatment in each trial. Pigs were housed in an environmentally controlled nursery in

[1]Oklahoma State University, Stillwater, OK.
[2]Food Animal Health and Management Center.
[3]Lonza, Inc., Fair Lawn, NJ.

5 × 5-ft pens on a commercial farm in northeastern Kansas. All pens contained one self-feeder and a nipple waterer to provide ad libitum access to feed and water.

Diets used in these two experiments were similar to those used in commercial production and were fed in four phases (d 0 to 4, 4 to 10, 10 to 24, and 24 to 38; Table 2). All phases consisted of five treatments: a control or the control diet with 25, 50, 75, or 100 ppm of added L-carnitine. Average daily gain, ADFI, and feed efficiency were determined by weighing pigs and measuring feed disappearance on day 4, 10, 24, and 38 after weaning (Table 4).

In Exp. 1, 2, and 3, the first two diets were pelleted at the Kansas State University Grain Science Feed Mill using a 5/32-in. diameter die and conditioned at 140°F. The last two diets were fed in meal form. All data in these three trials were analyzed as a randomized complete block design with pen as the experimental unit. Pigs were blocked on postweaning weight, and analysis of variance was performed using the GLM procedure of SAS.

The fourth trial was conducted at the Oklahoma State University Swine Research Center. One hundred twenty eight pigs (initially 12.1 lb and 21 ± 2 d of age) were used in a 38-d growth study. There were four to six pigs per pen and six pens/treatment. Pigs were allowed ad libitum access to feed and water.

Diets were fed in four phases (d 0 to 3, 3 to 10, 10 to 24, and 24 to 38; Table 3). Four experimental treatments were used: a control diet or the control diet with 25, 50, or 100 ppm of added L-carnitine. All diets were fed in meal form.

Results and Discussion

The data for the first three experiments have been combined (Table 3). No differences in ADG, ADFI, or F/G occurred with additional L-carnitine during phase I of these trials. During phase II, pigs fed increasing L-carnitine had increased (linear $P<.03$; quadratic, $P<.10$) ADG and improved F/G (linear $P<.01$, quadratic $P<.01$). However, a treatment × trial interaction was observed ($P<.01$) for F/G during this phase (Figure 1). In Exp. 3, increasing L-carnitine did not improve F/G to the same magnitude as in Exps. 1 and 2. Overall, pigs fed additional L-carnitine had greater (linear, $P<.06$) ADG and improved (linear, $P<.01$) feed efficiency compared to pigs fed the control diet. Although the responses in ADG and F/G for the overall study were linear, the greatest improvement was observed in pigs fed 25 to 50 ppm.

In Exp. 4, pigs fed increasing L-carnitine from d 0 to 3 had increased (linear, $P<.05$; Table 4) ADG and tended to have increased (linear, $P<.08$) ADFI. Then, from d 0 to 10, pigs fed increasing L-carnitine tended to be more efficient in converting feed to gain (linear, $P<.10$). During d 10 to 24, pigs fed increasing carnitine had increased (linear, $P<.03$) ADG and improved (linear, $P<.01$) F/G. Also, from d 24 to 38, pigs fed carnitine tended to have improved (quadratic, $P<.08$) F/G. Overall, pigs fed increasing L-carnitine tended to have increased (linear, $P<.09$) ADG and improved (quadratic, $P<.03$) F/G. For overall F/G, the greatest response was observed in pigs fed 50 ppm of added L-carnitine.

Like many studies evaluating vitamin requirements of pigs, some variation occurred in the magnitude of response to added L-carnitine. However, in general, we observed the greatest improvements to added L-carnitine in the phase II portion of our studies, and this was carried over to improve overall performance. These results suggest that 25 to 50 ppm of added L-carnitine can improve ADG and F/G in nursery pigs.

Table 1. Compositions of Basal Diets (Exp. 1)

Ingredient, %	D 0 to 7[a]	D 7 to 14[a]	D 14 to 24[b]	D 24 to 34[b]
Corn[c]	43.68	45.25	52.43	59.16
Soybean meal (46.5%)	17.00	24.68	26.25	32.38
Dried whey	20.00	15.00	10.00	-
Soy oil	5.00	5.00	4.00	4.00
Spray-dried animal plasma	5.00	2.50	-	-
Fish meal	2.50	-	-	-
Spray-dried blood cells	2.50	2.50	2.50	-
Monocalcium P (21% P)	1.26	1.70	1.68	1.56
Medication[d]	1.00	1.00	1.00	1.00
Limestone	.79	.99	.97	.95
Zinc oxide	.38	.38	.25	-
Vitamin premix	.25	.25	.25	.25
Salt	.20	.30	.25	.35
L-Lysine HCl	.15	.15	.15	.15
Trace mineral premix	.15	.15	.15	.15
DL-methionine	.15	.15	.13	.05
Total	100.00	100.00	100.00	100.00

[a]Fed in pelleted form.
[b]Fed in meal form.
[c]Corn was replaced by L-carnitine (wt/wt) to provide supplemental dietary L-carnitine levels of 25, 50, 75, and 100 mg/kg.
[c]Provided 50 g/ton carbadox.

Table 2. Compositions of Basal Diets (Exp. 2 & 3)

Ingredient, %	D 0 to 4[a]	D 4 to 10[a]	D 10 to 24[b]	D 24 to 38[b]
Corn	33.07	39.71	48.65	56.46
Soybean meal (46.5%)	12.71	23.01	27.33	34.29
Spray-dried whey	25.00	20.00	10.00	-
Spray-dried animal plasma	6.70	2.50	-	-
Fish meal	6.00	2.50	5.00	-
Soybean oil	6.00	5.00	5.00	5.00
Lactose	5.00	-	-	-
Spray-dried blood meal	1.65	2.50	-	-
Medication[c]	1.00	1.00	1.00	0.50
Monocalcium P (21% P)	0.75	1.30	1.00	1.50
Limestone	0.45	0.73	0.55	0.95
Corn starch[d]	0.40	0.40	0.40	0.40
Zinc oxide	0.38	0.38	0.25	-
Salt	0.20	0.30	0.25	0.35
Vitamin premix	0.25	0.25	0.25	0.25
Lysine HCl	0.15	0.15	0.15	0.15
DL-methionine	0.15	0.13	0.01	-
Trace mineral premix	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00

[a]Fed in pelleted form.
[b]Fed in meal form.
[c]Provided 50 g/ton carbadox from d 0 to 24 and 25 g/ton from d 24 to 38.
[d]Cornstarch was replaced by L-carnitine (wt/wt) to provide supplemental dietary L-carnitine levels of 25, 50, 75, and 100 mg/kg.

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

Ingredient, %	D 0 to 10	D 10 to 24	D 24 to 38
Corn	30.14	50.19	56.84
Soybean meal (48%)	20.75	25.00	33.75
Spray-dried whey	20.00	10.00	-
Lactose	10.00	-	-
Spray-dried animal plasma	5.00	2.50	-
Fish meal	2.50	-	-
Soybean oil	5.00	5.00	5.00
Spray-dried blood meal	2.50	2.50	-
Medication[a]	1.00	1.00	0.50
Dical P	1.53	2.11	2.37
Limestone	0.42	0.61	0.68
Corn starch[b]	0.10	0.10	0.10
Zinc oxide	0.28	0.28	-
Salt	0.25	0.25	0.35
TM/Vitamin premix	0.30	0.30	0.30
Copper sulfate	-	-	0.08
Ethoxyquin	0.03	0.03	0.03
DL-methionine	0.20	0.13	-
Total	100.00	100.00	100.00

[a]Provided 50 g/ton oxytetracycline and 140 g/ton neomycin from d 0 to 24, and 200 g/ton Lincomycin from d 24 to 38.
[b]Cornstarch was replaced by L-carnitine (wt/wt) to provide supplemental dietary L-carnitine levels of 25, 50, and 100 mg/kg.

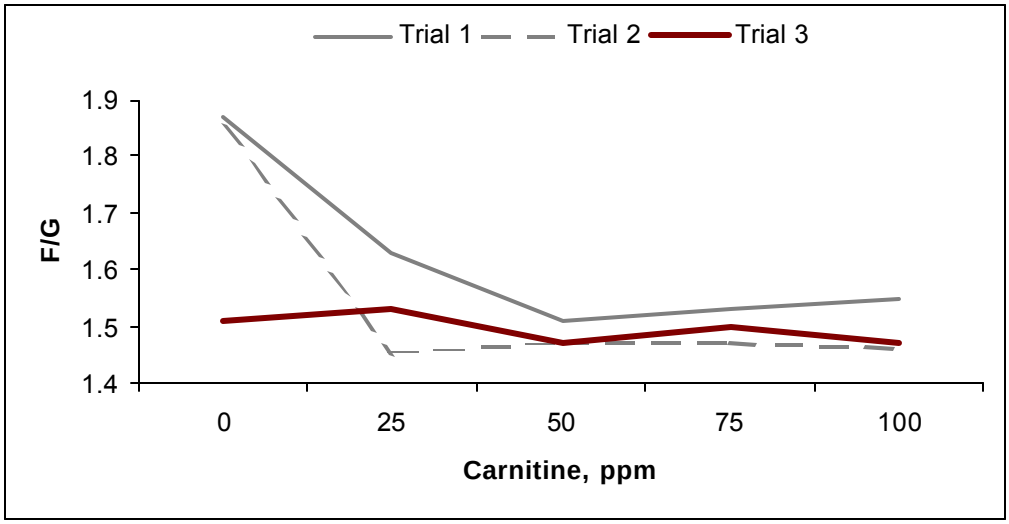


Figure 1. Effects of Increasing L-Carnitine on F/G in Exps. 1, 2, and 3. Treatment × trial interaction (P<.01) day 14 to 24 for Exp. 1, d 10 to 24 for Exps. 2 and 3.

Table 4. Effects of L-Carnitine on Nursery Pig Growth Performance[a]

	Carnitine, ppm						Probability				
Item	0	25	50	75	100	SEM	Carnitine	Trial	Trt×Trial	Linear	Quad.
Phase I[b]											
ADG, lb	.46	.47	.47	.47	.46	.015	.60	.01	.71	.66	.18
ADFI, lb	.50	.53	.52	.52	.50	.016	.27	.01	.30	.71	.62
F/G	1.10	1.15	1.12	1.12	1.13	.021	.31	.01	.87	.98	.17
Phase II[c]											
ADG, lb	.72	.78	.80	.81	.79	.027	.01	.01	.17	.03	.10
ADFI, lb	1.23	1.20	1.18	1.20	1.18	.030	.29	.01	.77	.29	.74
F/G	1.74	1.54	1.48	1.50	1.49	.033	.01	.01	.01	.01	.01
Phase III[d]											
ADG, lb	1.24	1.26	1.22	1.31	1.28	.037	.43	.26	.57	.19	.81
ADFI, lb	1.82	1.80	1.85	1.94	1.87	.051	.45	.19	.79	.14	.74
F/G	1.48	1.43	1.53	1.48	1.46	.024	.91	.88	.38	.94	.23
Overall											
ADG, lb	.80	.84	.83	.87	.84	.020	.04	.02	.74	.06	.30
ADFI, lb	1.10	1.18	1.19	1.23	1.20	.028	.70	.01	.86	.48	.81
F/G	1.48	1.41	1.43	1.42	1.40	.012	.01	.22	.54	.01	.13

[a]Values are representatives of three trials. Trial 1 had 196 pigs initially 10.6 lb and 10 to 14 days old with 8 pigs per pen and 5 pens per treatment. Trial 2 had 240 pigs initially 10.7 lb and 10 to 14 days of age with 8 pigs per pen and 6 replicates per treatment. Trial 3 had 190 pigs on test with 4 or 5 pigs per pen and 8 pens per treatment.
[b]Phase I is from day 0 to 14 in trial 1 and d 0 to 10 in trials 2 and 3.
[c]Phase II is from day 14 to 24 in trial 1 and from d 10 to 24 in trials 2 and 3.
[d]Phase III is from day 24 to 34 in trial 1 and from d 24 to 38 in trials 2 and 3.

Table 5. Effects of Added L-Carnitine on Weanling Pig Growth Performance (Exp. 4)[a]

	L-Carnitine, ppm					Probability		
Item	0	25	50	100	SEM	Linear	Quad.	Cubic
Day 0 to 3								
ADG, lb	.05	.12	.14	.16	.03	.05	.32	.78
ADFI, lb	.15	.17	.18	.20	.02	.08	.81	.88
F/G	2.72	1.33	1.61	1.37	.82	.37	.47	.54
Day 3 to 10								
ADG, lb	.41	.38	.46	.43	.04	.43	.71	.19
ADFI, lb	.48	.45	.50	.47	.03	.83	.79	.23
F/G	1.18	1.25	1.12	1.12	.07	.31	.90	.25
Day 0 to 10								
ADG, lb	.30	.30	.36	.35	.03	.18	.51	.32
ADFI, lb	.38	.37	.41	.39	.02	.55	.77	.30
F/G	1.28	1.30	1.14	1.14	.07	.10	.70	.31
Day 10 to 24								
ADG, lb	.75	.79	.84	.83	.02	.03	.16	.63
ADFI, lb	1.03	1.03	1.08	1.05	.02	.44	.35	.39
F/G	1.37	1.31	1.29	1.27	.02	.01	.12	.73
Day 24 to 38								
ADG, lb	1.06	1.08	1.13	1.09	.03	.49	.27	.66
ADFI, lb	1.72	1.72	1.74	1.80	.06	.31	.79	.96
F/G	1.63	1.59	1.54	1.66	.04	.61	.08	.68
Overall								
ADG, lb	.74	.76	.81	.80	.02	.09	.22	.48
ADFI, lb	1.11	1.11	1.14	1.15	.03	.27	.99	.68
F/G	1.50	1.45	1.39	1.44	.02	.16	.03	.58

[a]Values are means of 128 pigs (initially 12.1 lb and 21 ± 2 d of age) with 4 to 6 pigs per pen and 6 replicate pens per treatment.

EFFECTS OF A SEAWEED EXTRACT ON WEANLING PIG GROWTH PERFORMANCE AND IMMUNE FUNCTION DURING AN ACUTE ENTERIC DISEASE CHALLENGE[1]

J. L. Turner, S. S. Dritz[2], J. R. Werner, C. M. Hill, K. Skjolaas, S. Hogge[2], and J.E. Minton

Summary

A total of 95 pigs (initially 15 lb and 17 d of age) was used in a 28 d growth trial to determine the effects of *Ascophyllum nodosum* seaweed extract (ANOD) on weanling pig growth performance and immune function in response to enteric disease challenge with *Salmonella typhimurium* (ST). Experimental treatments were arranged in a 2 x 4 factorial with main effects of disease challenge (control vs. ST challenge) and dietary addition of ANOD (0, 0.5, 1.0, and 2.0% of diet). Results suggest little beneficial effect of dietary ANOD on growth performance or immune response in the presence or absence of ST challenge.

(Key Words: Weanling Pigs, Disease Challenge, *Salmonella*, Seaweed.)

Introduction

Antibiotics are used extensively in livestock feeding to prevent infection and to improve growth performance and feed efficiency. Today, the use of antibiotics in animal diets has come under increased public scrutiny because of concern about the development of antibiotic-resistant organisms. Management programs (e.g., segregated early weaning, all-in/all-out production) help to minimize exposure to pathogens; however, acute disease challenges still occur. Therefore, research studying natural alternatives to dietary antimicrobials is on the rise.

Preliminary research at another university suggests that the addition of an extract from the seaweed *Ascophyllum nodosum* (ANOD) may enhance growth performance and immune function in porcine respiratory and reproductive syndrome (PRRS) virus-infected nursery pigs. The objective of the current study was to determine the effects of ANOD supplementation (without dietary antibiotics) on growth performance and immune function of nursery pigs with a bacterial challenge of *Salmonella typhimurium* (ST).

Procedures

The experimental protocol used in this study was approved by the KSU Institutional Animal Care and Use Committee. The 95 pigs (initially 15 lb and 17 d of age) were blocked by initial weight, equalized for sex, and allotted randomly to one of eight treatments in a 28 d growth assay. Each treatment had six replicates (pens) with two pigs per pen.

The eight treatments were arranged in a 2 × 4 factorial with main effects of disease challenge (control or ST) and dietary treatment (Table 1; 0, 0.5, 1.0, or 2.0% ANOD). The ANOD extract used in this study was obtained from Acadian Seaplants Limited, Nova Scotia, Canada.

All pigs were housed in two similar environmentally controlled rooms according

[1]The authors gratefully acknowledge funding by the National Pork Producers Council, on behalf of the National Pork Board, and donation of product for the study by Acadian Seaplants Limited.

[2]Food Animal Health and Management Center.

to disease challenge. Pens contained one self-feeder and one nipple waterer to provide ad libitum access to feed and water. Prior to the start of the study, fecal samples were taken to ensure that all pigs were free of *Salmonella*. Pigs were weighed and feed disappearance was measured on d 0, 7, 14, 21, and 28 to determine ADG, ADFI, and F/G. On d 14, each pig housed in the ST room (n=48) were orally gavaged with approximately 6 x 10^9 CFU of *S. typhimurium* in 10 ml of growth medium. Each pig housed in the control room (n=47) received a similar volume of sterile growth medium. Rectal temperature was measured on one pig per pen through 7 d after challenge. Daily feed intake also was monitored through 7 d after challenge. On d 0, 7, and 14 with respect to challenge, serum samples were obtained from one pig per pen and analyzed for haptoglobin. On d 7 and 14 after challenge, fecal samples were obtained from all pigs and cultured for *Salmonella*.

Data were analyzed as a 2 × 4 factorial in a randomized complete block design replicated over time using the mixed model procedure of SAS. All means presented are least-square means.

Table 1. Diet Composition (As-Fed Basis)

Ingredient	% of Diet
Corn	49.65
Soybean meal (46.5% CP)	28.03
Spray-dried whey	10.00
Select menhaden fish meal	4.50
Choice white grease	3.00
Cornstarch[a]	2.00
Monocalcium phosphate	1.20
Limestone	0.68
Salt	0.35
Vitamin premix	0.25
Trace mineral premix	0.15
L-Lysine HCl	0.15
DL-Methionine	0.05

[a]ANOD extract replaced cornstarch to provide the experimental treatments.
Diet was formulated to contain 1.40% lysine, 0.90% Ca, and 0.79% P.

Results and Discussion

No differences (P>.10) in ADG, ADFI, or F/G occurred between dietary treatments (Table 2). However, a challenge by time interaction (P<.0005) was observed. Prior to challenge, ADG, ADFI, and F/G were similar between control and ST-challenged pigs. The ST challenge resulted in reductions in ADG (P<.0001), ADFI (P<.005), and F/G (P<.002) compared to controls during wk 3 of the study (Table 2). However, by wk 4, ADFI did not differ (P>.10) between control and ST-challenged pigs. This increased ADFI for ST-challenged pigs resulted in improved (P<.05) ADG and F/G compared to controls in wk 4.

During the 7 d after challenge, a challenge by time interaction (P<.0001) affected daily feed intake and rectal temperature. Daily feed intake for ST-challenged pigs began to decline (P<.05) between 24 to 48 h after challenge (Table 3), but returned to levels comparable to those of controls by 5 d after challenge. Rectal temperature (Table 3) of control pigs did not differ during the 7 d after challenge. The ST-challenged pigs had a higher (P<.05) rectal temperature than controls on 0 d. The ST-challenge produced a marked febrile response. Rectal temperature in ST-challenged pigs was elevated on 1 d (P<.05), peaked on 2 d (P<.05), and returned to control levels by 4 d after challenge.

A diet by challenge interaction (P<.056) also occurred. Control pigs receiving the 0% ANOD diet had higher (P<.05) serum haptoglobin concentrations (Table 4) than control pigs receiving 2% ANOD or ST-challenged pigs receiving 0% ANOD. In addition, a challenge by time interaction (P<.0001) affected serum haptoglobin (Table 5). Haptoglobin levels for controls declined over time, whereas haptoglobin in ST-challenged pigs was elevated (P<.05) on 7 d after challenge, but returned to prechallenge levels by 14 d.

At 7 d after challenge, fecal cultures for control pigs were negative, whereas 21.3% (10/47) ST-challenged pigs were positive for

Salmonella. At 14 d after challenge, one control pig had a positive *Salmonella* culture, and 10.6% (5/47) of ST-challenged pigs were positive. Rectal temperature and serum haptoglobin levels for the one control pig that cultured positive were never elevated. Therefore, we were satisfied that biosecurity was maintained and attribute the positive culture to laboratory error.

The results of this study are consistent with previous studies, indicating that an acute challenge with ST results in increases in rectal temperature and serum haptoglobin with concomitant reductions in ADFI and ADG. Furthermore, the compensatory gain and improved F/G of ST-challenged pigs during wk 4 of the study suggests that the response to acute enteric disease challenge is transient and appears to have minimal impact on future performance. However, in a commercial setting, chronic exposure to pathogens and other stressors can compromise performance, and further research in this area is needed. In contrast to the previous study using a PRRS-virus challenge, we were unable to detect an effect of ANOD on growth performance and immune function in unchallenged controls or ST-challenged pigs.

Table 2. Effects of *Salmonella* Challenge and Dietary ANOD on Growth Performance of Weanling Pigs

	Salmonella			% ANOD in Diet				
Item	Control	Challenge	SEM	0	0.5	1.0	2.0	SEM
Day 0 to 7								
ADG, lb	.46[a]	.50[a]	.057	.43	.44	.49	.55	.071
ADFI, lb	.66[a]	.77[a]	.089	.60	.70	.74	.82	.110
F/G	1.52[ac]	1.59[c]	.084	1.47	1.66	1.56	1.53	.119
Day 8 to 14								
ADG, lb	.94[b]	1.04[b]	.057	.90	1.06	1.07	.94	.071
ADFI, lb	1.22[b]	1.36[b]	.089	1.15	1.29	1.35	1.37	.110
F/G	1.33[a]	1.32[a]	.084	1.34	1.22	1.28	1.47	.119
Day 15 to 21								
ADG, lb	1.39[c]	.95[b]	.057	1.12	1.19	1.25	1.14	.071
ADFI, lb	1.91[c]	1.62[d]	.089	1.68	1.84	1.83	1.71	.110
F/G	1.39[a]	1.85[bc]	.084	1.58	1.74	1.59	1.59	.119
Day 22 to 28								
ADG, lb	1.17[d]	1.40[c]	.057	1.27	1.28	1.37	1.24	.071
ADFI, lb	2.17[e]	2.29[e]	.089	2.14	2.20	2.24	2.34	.110
F/G	1.91[b]	1.65[c]	.084	1.74	1.81	1.62	1.94	.119

[a,b,c,d,e]Means within rows or columns without common superscripts differ (P<.05).

Table 3. Effects of *Salmonella* Challenge on Daily Feed Intake and Rectal Temperature of Weanling Pigs

Day after	Feed Intake, lb		Rectal Temperature, °F	
Challenge	Control	Challenge	Control	Challenge
0	--	--	103.5^{ab}	104.0^{cg}
1	1.79^{ace}	1.70^{eg}	103.6^{ab}	104.6^{d}
2	1.77^{ae}	$.90^{d}$	103.6^{abc}	105.2^{e}
3	1.84^{afg}	1.18^{dh}	103.6^{ab}	104.3^{g}
4	2.11^{bf}	1.49^{eh}	103.5^{ab}	103.8^{ac}
5	1.98^{afg}	2.05^{af}	103.9^{ac}	103.6^{ab}
6	1.87^{acfg}	2.01^{bcf}	103.8^{abc}	102.8^{f}
7	2.09^{bcfg}	2.02^{bcf}	103.4^{b}	103.0^{f}

^{a,b,c,d,e,f,g,h}Means within rows or columns without common superscripts differ (P<.05); Feed intake SEM = ± 0.145; Rectal temperature SEM = ± 0.134.

Table 4. Effect of Dietary ANOD on Haptoglobin Concentration (mg/dl) of Weanling Pigs

Diet (% ANOD)	Control	Challenge
0	43.50^{a}	20.17^{b}
0.5	25.94^{ab}	35.41^{ab}
1	33.00^{ab}	36.15^{ab}
2	21.28^{b}	27.67^{ab}

^{a,b}Means within rows or columns without common superscripts differ (P<.05); SEM = ± 6.50.

Table 5. Effect of *Salmonella* Challenge on Haptoglobin Concentration (mg/dl) of Weanling Pigs

Day after Challenge	Control	Challenge
0	44.13^{a}	27.17^{c}
7	25.88^{bc}	35.67^{ab}
14	22.79^{c}	26.71^{c}

^{a,b,c}Means within rows or columns without common superscripts differ (P<.05); SEM = ± 4.13.

EFFECTS OF A *QUILLAJA SAPONARIA* EXTRACT ON WEANLING PIG GROWTH PERFORMANCE AND IMMUNE FUNCTION DURING AN ACUTE ENTERIC DISEASE CHALLENGE[1]

J. L. Turner, S. S. Dritz[2], J. R. Werner, C. M. Hill, K. Skjolaas, S. Hogge[2], K. Herkleman[3], and J. E. Minton

Summary

A total of 96 pigs (initially 19 lb and 17 d of age) was used in a 28 d growth trial to determine the effects of *Quillaja saponaria* (QS) extract on weanling pig growth performance and immune function in response to enteric disease challenge with *Salmonella typhimurium* (ST). Experimental treatments were arranged in a 2 × 4 factorial with main effects of disease challenge (control vs. ST challenge) and dietary addition of QS (0, 4, 8, or 16 oz/ton). The results suggest little beneficial effect of QS on growth performance or immune response in the presence or absence of ST challenge.

(Key Words: Weanling Pigs, Disease Challenge, *Salmonella, Quillaja.*)

Introduction

The popular press and empirical evidence have suggested that many plant extracts offer benefits in terms of boosting the immune system and preventing disease. Furthermore, there is growing sentiment among scientists and the general public to find alternatives for feed-grade antibiotics to promote growth and prevent disease in food animal production systems.

The extract of the South American tree, *Quillaja saponaria* (QS), has been widely used over the past three decades as a vaccine adjuvant (Quil A). The active ingredient appears to be the saponin fraction. Recent studies have shown that saponins can inhibit *in vitro* growth of *E. coli* and alter the rumen microflora *in vivo*. The objective of the present study was to determine the effects of dietary supplementation with a crude QS extract on growth performance and immune function of weanling pigs challenged with ST.

Procedures

The experimental protocol used in this study was approved by the KSU Institutional Animal Care and Use Committee. The 96 pigs (initially 19 lb and 17 d of age) were blocked by initial weight, equalized for sex, and allotted randomly to one of eight treatments in a 28 d growth assay. Each treatment had six replicates (pens) with two pigs per pen.

The eight treatments were arranged in a 2 × 4 factorial with main effects of disease challenge (control or ST) and dietary treatment (Table 1; 0, 4, 8, or 16 oz/ton of added QS). The QS extract used in this study was obtained from Desert King, Inc., Chula Vista, California.

All pigs were housed in two similar environmentally controlled rooms according to disease challenge. Pens contained one self-feeder and one nipple waterer to provide ad libitum access to feed and water. Prior to the start of the study, fecal samples were

[1]The authors gratefully acknowledge the financial support from Desert King International.

[2]Food and Animal Health and Management Center.

[3]Farmland Industries, Inc., Kansas City, MO.

taken to ensure that all pigs were free of *Salmonella*. Pigs were weighed and feed disappearance was measured on d 0, 7, 14, 21, and 28 to determine ADG, ADFI, and F/G. On d 14, each pig housed in the ST room (n=48) were orally gavaged with approximately 10.5×10^9 CFU of *S. typhimurium* in 10 ml of growth medium. Each pig housed in the control room (n=48) received a similar volume of sterile growth medium. Rectal temperature was measured on one pig per pen through 7 d after challenge. Daily feed intake also was monitored through 7 d after challenge. On d 0, 7, and 14 with respect to challenge, serum samples were obtained from one pig per pen and analyzed for haptoglobin. On d 7 and 14 after challenge, fecal samples were obtained from all pigs and cultured for *S. typhimurium*.

Data were analyzed as a 2 × 4 factorial in a randomized complete block design replicated over time using the mixed model procedure of SAS. All means presented are least-square means.

Table 1. Diet Composition (As-Fed Basis)

Ingredient	% of Diet
Corn	51.72
Soybean meal (46.5% CP)	27.86
Spray-dried whey	10.00
Select menhaden fish meal	4.50
Choice white grease	3.00
Monocalcium phosphate	1.20
Limestone	0.68
Salt	0.35
Vitamin premix	0.25
Trace mineral premix	0.15
L-Lysine HCl	0.15
Cornstarch[a]	0.10
DL-Methionine	0.05

[a]*Quillaja saponaria* extract replaced cornstarch to provide the experimental treatments.
Diet was formulated to contain 1.40% lysine, 0.90% Ca, and 0.79% P.

Results and Discussion

No differences (P>.10) in ADG, ADFI, or F/G occurred between dietary treatments (Table 2). However, a challenge by time interaction (P<.0001) was observed (Table 2). Prior to challenge, ADG, ADFI, and F/G were similar between control and ST-challenged pigs. However, ST challenge resulted in reduced ADG (P<.0001), ADFI (P<.0001), and F/G (P<.0001) as compared to controls during wk 3 of the study. The negative impact of ST challenge on growth performance was resolved quickly, and ADG, ADFI, and F/G did not differ between control and ST-challenged pigs during wk 4.

During wk 1 after challenge, a challenge by day interaction (P<.0001) affected daily feed intake and rectal temperature (Table 3). Daily feed intake for the ST-challenged pigs dropped dramatically between 24 to 48 h after challenge, remained depressed through 5 d after challenge, and returned to levels comparable to controls by d 6 after challenge. Rectal temperature of control pigs remained constant during the 7 d after challenge, but ST challenge resulted in a febrile response. Rectal temperature of ST-challenged pigs was higher (P<.05) on d 1 to 4 after challenge, but returned to levels similar to controls by d 5 after challenge.

A challenge by day interaction (P<.0001) affected serum insulin-like growth factor-1 (IGF-1) concentrations (Table 4). IGF-1 did not differ between control and ST-challenged pigs prior to challenge. *Salmonella typhimurium* challenge resulted in a reduction in circulating IGF-1 on d 2 and 4 after challenge. Although IGF-1 in ST-challenged pigs began to increase by d 6, it was still lower (P<.05) than that of controls.

A challenge by time interaction (P<.002) affected serum haptoglobin concentration (Table 5). *Salmonella typhimurium* challenge produced a rise (P<.0001) in serum haptoglobin on d 7 after challenge, but levels were comparable to those of controls by d 14 after challenge.

On 7 d after challenge, one control pig cultured positive for *Salmonella*. However, the rectal temperature of this pig remained constant through 7 d after challenge, and serum haptoglobin levels on d 7 and 14 after challenge were actually lower than the pre-challenge level. Therefore, we were satisfied that biosecurity was maintained and attribute the positive culture to laboratory error. On d 7 after challenge, 68.75% (33/48) of the ST-challenged pigs had a positive culture for *Salmonella*. At 14 d after challenge, the percentage of ST-challenged pigs shedding *Salmonella* had dropped to 20.83% (10/48), and no control pigs had positive culture results.

No differences in total white blood cell count, red blood cell count, hemoglobin, hematocrit, or phagocytic function of peripheral white blood cells isolated from ST-challenged pigs occurred on d 6 versus d 13 after challenge (data not shown). A diet effect ($P<.05$) was observed. The higher inclusion levels of QS (8 and 16 oz/ton) appeared to depress phagocytic function of peripheral white blood cells (Table 6).

The results of this trial agree with previous studies using this disease challenge model to document the detrimental effects of enteric infection on growth performance, feed intake, and IGF-1. In contrast to a similar study by our laboratory using this same model of disease challenge, compensatory gain and improved F/G for ST-challenged pigs during the second wk after challenge were not observed. However, growth performance of ST-challenged pigs was comparable to that of controls during wk 4 of the study. This was accompanied by a decrease in serum haptoglobin and the return of IGF-1 to prechallenge levels. This further supports the concept that an acute enteric disease challenge in weanling pigs results in only transient alterations in growth performance.

Quillaja saponaria extract appears to influence phagocytic cell function in a quadratic fashion (4 oz vs. 8 or 16 oz/ton). From a physiological perspective, this impact of QS supplementation seems marginal. Thus, in summary, inclusion of QS, at the levels reported herein, apparently has little benefit on growth performance or immune function in unchallenged controls or ST-challenged pigs.

Table 2. Effects of *Salmonella* Challenge and Dietary QS on Growth Performance of Weanling Pigs

	Salmonella			Dietary Level of QS (oz/ton)				
Item	Control	Challenge	SEM	0	4	8	16	SEM
Day 0 to 7								
ADG, lb	.88[a]	.90[a]	.050	.91	.85	.93	.88	.067
ADFI, lb	1.12[a]	1.13[a]	.060	1.08	1.04	1.28	1.11	.077
F/G	1.29[a]	1.27[a]	.067	1.20	1.24	1.38	1.29	.095
Day 8 to 14								
ADG, lb	1.21[bd]	1.33[d]	.050	1.21	1.31	1.24	1.32	.067
ADFI, lb	1.81[e]	1.96[b]	.060	1.87	1.85	1.90	1.92	.077
F/G	1.53[b]	1.48[b]	.067	1.60	1.42	1.55	1.46	.095
Day 15 to 21								
ADG, lb	1.55[c]	.90[a]	.050	1.21	1.21	1.21	1.26	.067
ADFI, lb	2.32[c]	1.71[e]	.060	2.01	1.94	2.10	2.02	.077
F/G	1.52[b]	2.14[c]	.067	1.86	1.84	1.83	1.78	.095
Day 22 to 28								
ADG, lb	1.67[ce]	1.69[e]	.050	1.61	1.76	1.68	1.66	.067
ADFI, lb	2.72[d]	2.73[d]	.060	2.64	2.74	2.85	2.67	.077
F/G	1.64[b]	1.64[b]	.067	1.69	1.56	1.69	1.61	.095

[a,b,c,d,e]Means within rows or columns without common superscripts differ ($P<.05$).

Table 3. Effects of *Salmonella* Challenge on Daily Feed Intake and Rectal Temperature of Weanling Pigs

	Feed Intake, lb		Rectal Temperature, °F	
Day after Challenge	Control	Challenge	Control	Challenge
0	- -	- -	103.6[ad]	103.6[ad]
1	2.23[a]	2.12[ah]	103.5[ad]	104.4[cf]
2	2.15[ah]	.87[e]	103.3[ab]	104.6[c]
3	2.28[ac]	1.16[f]	103.3[ab]	104.1[fg]
4	2.30[adi]	1.53[g]	103.1[b]	103.9[dg]
5	2.59[b]	1.90[h]	103.4[abe]	103.6[ad]
6	2.33[ab]	2.08[ah]	103.2[ab]	103.8[deg]
7	2.50[bci]	2.34[ab]	103.6[ad]	103.8[deg]

a,b,c,d,e,f,g,hMeans within rows or columns without common superscripts differ (P<.05); feed intake SEM = ±0.113; rectal temperature SEM = ±0.170.

Table 4. Effect of *Salmonella* Challenge on IGF-1 Concentration (ng/ml) of Weanling Pigs

Day after Challenge	Control	Challenge
0	149.18[a]	180.92[ab]
2	161.94[a]	46.87[c]
4	154.93[a]	50.81[c]
6	206.09[b]	149.87[a]

[a,b,c]Means within rows or columns without common superscripts differ (P<.05); SEM = ± 19.351.

Table 5. Effect of *Salmonella* Challenge on Haptoglobin Concentration (mg/dl) of Weanling Pigs

Day after Challenge	Control	Challenge
0	23.83[a]	22.92[a]
7	21.25[a]	35.96b
14	19.50[a]	22.25[a]

[a,b]Means within rows or columns without common superscripts differ (P<.05); SEM = ± 2.599.

Table 6. Effect of Dietary *Quillaja saponaria* (QS) on Phagocytic Function and Oxidative Burst Activity of Phagocytic Cells from Weanling Pigs Challenged with *Salmonella typhimurium*

Diet (oz/ton QS)	% of Cells Reacting
0	37.25[ab]
4	40.46[b]
8	31.78[a]
16	34.09[a]

[a,b]Means without common superscripts differ (P<.05); SEM = ± 2.539.

INFLUENCE OF CALCIUM PROPIONATE ON STARTER PIG PERFORMANCE[1]

D. E. Real, M. D. Tokach, J. L. Nelssen, R. D. Goodband, S. S. Dritz[2], J. C. Woodworth, and M. J. Webster

Summary

A 24-d growth study was conducted to evaluate the effects of low rates of a dietary acidifier, calcium propionate, on weanling pig growth performance. Experimental diets, fed from d 0 to 10, were a control diet with no acidifier, the control diet with 4 lb/ton of Kemgest, or the control diet with 4 or 8 lb/ton calcium propionate. From d 10 to 24, pigs were fed a common phase II diet containing no acidifier. Adding a low rate of acidifier to the diet had no influence on pig performance.

(Key Words: Acidifiers, Nursery Pigs, Calcium Propionate.)

Introduction

Recent trials have indicated that ADG and F/G can be improved when low rates of acidifiers are added to diets fed immediately after weaning. Acidifiers that have been tested include Kemgest, Syneracid, Luprosil, and Digest Acid. Other low inclusion-rate acidifiers are also available, but have not received thorough testing for their potential impact on starter pig performance. A propionic acid source being used by many producers in Kansas fits this description. Therefore, the purpose of this trial was to determine the influence of that propionic acid source (calcium propionate) on starter pig performance.

Procedures

A total of 192 pigs (initially 10.8 lb and 12 ± 2 d of age) were used in a 24-d growth assay. Pigs were blocked by weight and allotted to one of four dietary treatments. There were eight pigs per pen and six pens per treatment. Pigs were housed in an environmentally controlled nursery in 5 × 5-ft pens on a commercial farm in northeastern Kansas. All pens contained one self-feeder and a nipple waterer to provide ad libitum access to feed and water.

From d 0 to 4, pigs were fed an SEW diet formulated to contain 1.70% lysine (Table 1). A transition diet formulated to contain 1.6% lysine was fed from day 4 to 10. At day 10, pigs were switched to a common diet formulated to 1.55% lysine. The SEW and transition diets were pelleted at the Kansas State University Grain Science feed mill using a 5/32-in. diameter die. Four experimental diets were fed during each phase: a control with no added acidifier, 4 lb/ton added Kemgest, 4 lb/ton added calcium propionate, and 8 lb/ton added calcium propionate. The pigs were fed a common phase II (Table 1) diet in meal form from d 10 to 24.

Average daily gain, ADFI, and feed efficiency were determined by weighing pigs and measuring feed disappearance on day 4, 10, 17, and 24 after weaning. All data were analyzed as a randomized complete block design with pen as the experimental unit. Pigs were blocked on postweaning weight, and analysis of variance was performed using the GLM procedure of SAS.

[1]The authors thank Ken Anderson of Eichman Brothers Pork for technical assistance. The authors also thank Kemin Industries for donation of Kemgest.

[2]Food Animal Health and Management Center.

Results and Discussion

From d 0 to 10, no significant differences(P>.05) in ADG, ADFI, or F/G occurred among treatments (Table 2). Adding calcium propionate to the diet tended (P<.08) to increase ADFI from d 0 to 10, however, this did not significantly affect ADG or F/G. Experimental diets fed from d 0 to 10 did not influence subsequent performance from d 10 to 24. For the trial, ADG, ADFI, and F/G were similar among treatments.

Several experiments have indicated that adding acidifiers to diets for segregated early-weaned pigs increases growth performance. Young pigs 2 to 3 weeks old, which are just starting on feed, have relatively low secretions of HCl, gastrin, pancreatic lipase, amylase, and trypsin from the stomach and pancreas. These all are released in partial response to a low pH in the intestine. Lowering the pH by the use of organic acids theoretically can increase the secretion and activity of these enzymes.

Prior research at Kansas State University has shown that adding acidifiers to diets (containing 25% dried whey and 7.5% plasma) improved feed efficiency by as much as 19% during the first 7 days postweaning. Another trial demonstrated that adding fumaric acid to the diet (containing 20% dried whey and 10% plasma) resulted in tendencies to improve ADG and F/G. However, we did not see statistical improvements in growth performance with the addition of acidifiers in this trial.

The observed trends are similar to what has been seen in past trials. Calcium propionate, a relatively inexpensive source of organic acids, may be needed at higher concentrations to affect growth performance in the nursery. Further experiments are necessary to determine the value of calcium propionate in nursery diets.

Table 1. Compositions of Basal Diets

Ingredient, %	SEW	Transition	Phase II
Corn	33.07	39.72	-
Milo	-	-	48.69
Soybean meal (46.5%)	12.71	23.01	28.25
Spray-dried whey	25.00	20.00	10.00
Spray-dried animal plasma	6.70	2.50	-
Fish meal	6.00	2.50	5.00
Soybean oil	6.00	5.00	-
Choice white grease	-	-	5.00
Lactose	5.00	-	-
Spray-dried blood meal	1.65	2.50	-
Medication[a]	1.00	1.00	0.25
Monocalcium P (21% P)	0.75	1.30	1.00
Limestone	0.45	0.73	0.60
Salt	0.20	0.30	0.25
Vitamin premix	0.25	0.25	0.25
Zinc oxide	0.38	0.38	0.06
Corn starch[b]	0.40	0.40	-
Lysine HCl	0.15	0.15	0.15
DL-methionine	0.15	0.13	0.05
Trace mineral premix	0.15	0.15	0.15

[a]Provided 50 g/ton carbadox d 0 to 10, 50 g/ton tylosin d 10 to 24.
[b]Cornstarch was replaced by acidifier to achieve treatments.

Table 2. Influence of Calcium Propionate on Nursery Pig Performance[a]

			Ca Propionate			Contrast
Item	Control	Kemgest	4 lb/ton	8 lb/ton	SEM	Control vs. Acidifier
Day 0 to 10						
ADG, lb	.42	.42	.44	.45	.016	.60
ADFI, lb	.45	.44	.47	.49	.012	.08
F/G	1.09	1.06	1.08	1.10	.040	.86
Day 10 to 24						
ADG, lb	.81	.82	.82	.85	.026	.73
ADFI, lb	1.09	1.09	1.13	1.12	.030	.55
F/G	1.32	1.33	1.38	1.32	.036	.66
Day 0 to 24						
ADG, lb	.65	.65	.66	.68	.015	.41
ADFI, lb	.82	.82	.86	.86	.019	.28
F/G	1.26	1.26	1.29	1.26	.027	.76

[a]Values are means of 192 pigs (initially 11.6 lb and 15 to 21 d of age) with 8 pigs per pen and 6 replicate pens per treatment.

EFFECTS OF SORGHUM GENOTYPE ON MILLING CHARACTERISTICS AND GROWTH PERFORMANCE OF NURSERY PIGS

C. L. Jones, J. D. Hancock, K. C. Behnke[1], C. M. Sowder[2], and L. J. McKinney[1]

Summary

The sorghums used in our experiment (mill-run, red feed-quality, and white food-quality) had greater true grinding efficiency than corn. Mill-run sorghum also ground easier and with greater true efficiency than the red and food quality (white seed/tan plant) experimental sorghums. Diets with the red sorghum had greater pellet production rate and pellet durability index than diets with the food-quality sorghum. In a nursery pig growth assay, corn-based diets had greater digestibility of gross energy than the sorghum diets, and the white sorghum had greater digestibilities of dry matter, nitrogen, and gross energy than the red sorghum. However, ADG, ADFI, and G/F were not different among pigs fed the various cereal grains.

(Key Words: Nursery Pigs, Sorghum, Food Quality.)

Introduction

Worldwide, more than 50% of the sorghum produced is used for human food. However, less than 2% of domestic sorghum produced is used for human food. Consequently, there is interest in developing food-quality sorghums for production in the United States to increase sorghum's value in the export market. Food-quality sorghums traditionally have been selected for color (white seed/tan plant) and milling characteristics with little regard given to their nutritional value. With the increased production of food-quality sorghum, it will find its way into the livestock feeding industry. Thus, we designed an experiment to determine the milling characteristics and feeding value of a food-quality sorghum adapted for production in Kansas.

Procedures

A total of 192 weanling pigs, averaging 21 days of age and 15 lb BW, was used in a 35-d growth assay. The pigs were blocked by weight and allotted to pens based on sex and ancestry. There were eight pens/ treatment with six pigs/pen. The pigs were housed in 3.5-ft x 5-ft pens having a self-feeder and nipple waterer to allow ad libitum consumption of food and water. Treatments were: 1) mill-run corn (control); 2) mill-run sorghum (control); 3) Asgrow A570 (red seed/purple plant); 4) Asgrow 6126 (white seed/tan plant). The diets (Table 1) were formulated to 1.7% lysine for d 0 to 7, 1.55% lysine for d 7 to 21, and 1.4% lysine for d 21 to 35. At the end of each phase, pigs and feeders were weighed to allow calculation of ADG, ADFI, and F/G.

The cereals were ground through a Jacobson Hammermill using a 6/64" screen. A volt/amp meter was used to determine grinding efficiency and particle size was determined by sieving. Pelleting was accomplished using a CPM Master Model HD pellet mill equipped with a 5/32" by 1 ¼" die. Phase 1 diets were pelleted at 140°F, and phase 2 and 3 diets were pelleted at 180°F.

[1]Department of Grain Science and Industry.
[2]Asgrow Seed Company, Halstead, KS.

Results and Discussion

Grinding data (Table 2) indicated no differences in energy consumption or production rate among corn and the sorghums (P>.38). However, the sorghums had greater true grinding efficiency than corn (P<.04), and this difference resulted primarily from the greater true grinding efficiency of the mill-run sorghum. Indeed, mill-run sorghum required less net energy to grind (P<.02) and had greater true grinding efficiency (P<.001) than the two Asgrow hybrids. Finally, the food-quality sorghum required more total energy to grind (P<.01) and had a lower production rate (P<.001) compared to the red sorghum.

In the pelleting experiment, no differences in energy consumption occurred among diets based on the four cereals (P>.39). However, corn did show a trend for greater production rate (P<.10) vs the sorghums and the red feed-quality sorghum had a greater production rate (P<.04) than the white food-quality sorghum. Diets pelleted with the red sorghum also had greater standard and modified pellet durability indexes than diets with food-quality sorghum (P<.04).

During d 0 to 7 of the growth assay with nursery pigs, corn supported greater ADG (P<.02) and lower F/G (P<.04) than the sorghum diets. However, for d 7 to 21, the pigs fed sorghum-based diets had greater ADG (P<.05) than pigs fed the corn-based diet. Thus, for the overall period (i.e., d 0 to 35), no differences in growth performance (P>.13) occurred among pigs fed the corn- and sorghum-based diets. As for pigs fed the various sorghums, the red sorghum supported greater ADG than the white sorghum (P<.03) for d 0 to 7, and pigs fed the red and white sorghums had better F/G (P < .05) than pigs fed the mill-run sorghum for d 7 to 21. These were the only significant effects on growth performance. Thus, there is little reason to suggest that any of the sorghums had superior feeding value.

Digestibilities of nitrogen (N) (P<.06) and gross energy (GE) (P<.04) were greater for the corn-based diet than the sorghum-based diets. However, diets with the white sorghum had greater digestibilities (P < .01) of dry matter, N, and GE than diets with the red sorghum, and digestibility of nutrients in the white sorghum compared nicely to those for corn-based diets.

In conclusion, our results demonstrated that sorghum can be substituted for corn in nursery diets with no effect on growth performance. Also, the white food-quality sorghum supported growth performance and nutrient digestibilities equal to those of corn.

Table 1. Compositions of Diets[a]

	d 0 to 7		d 7 to 21		d 21 to 35	
Item, %	Corn	Sorghum	Corn	Sorghum	Corn	Sorghum
Corn	29.71	—	52.39	—	63.35	—
Sorghum	—	29.73	—	52.39	—	63.35
Soybean meal	24.70	24.70	28.48	28.49	30.39	30.42
Whey	20.00	20.00	10.00	10.00	—	—
Lactose	10.00	10.00	—	—	—	—
Plasma protein	4.00	4.00	—	—	—	—
Wheat gluten	4.00	4.00	—	—	—	—
Fishmeal	2.00	2.00	4.00	4.00	—	—
Soy oil	1.00	1.00	1.00	1.00	1.00	1.00
Monocalcium phosphate	1.26	1.24	.79	.76	1.50	1.47
Limestone	.85	.86	.72	.73	1.11	1.13
Lysine	.36	.38	.36	.40	.42	.45
Methionine	.15	.15	.15	.16	.15	.16
Threonine	.09	.09	.15	.14	.16	.15
Valine	.02	—	.04	—	.05	—
Tryptophan	.01	—	.02	—	.02	—
Salt	.20	.20	.25	.25	.36	.38
Vitamin premix	.15	.15	.25	.25	.25	.25
Mineral premix	.10	.10	.15	.19	.15	.15
Copper sulfate	—	—	—	—	.09	.09
Zinc oxide	.40	.40	.25	.24	—	—
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00	1.00

[a]Diets were formulated to 1.7% lysine, .9% Ca, and .8% P for d 0 to 7; 1.55% lysine, .8% Ca and .7% P for d 7 to 21; and 1.4% lysine, .8% Ca and .7% P for d 21 to 35.

[b]Supplied 150 g/ton apramycin for d 0 to 7 and 7 to 21 and 50 g/ton mecadox for d 21 to 35.

Table 2. Production Characteristics for Phase 3 Diets

	Treatments					Contrast[c]		
Item	Corn	Mill-Run Sorg	Red Sorg	White Sorg	SE	1	2	3
Hammermill data								
Production rate, lb/h	2,783	2,547	3,123	2,497	55	—[d]	.008	.001
Energy consumption, kWh/t								
Total	13.7	13.8	13.1	15.2	.4	—	—	.01
Net	7.2	6.6	7.3	8.0	.3	—	.02	—
True efficiency, ft^2/Wh	15.5	22.4	14.7	14.3	.7	.04	.001	—
Pelleting data								
Production rate, lb/h	4,635	4,343	4,610	4,166	118	.11	—	.04
Energy consumption, kWh/t								
Net[a]	3.9	4.2	4.0	4.1	.2	—	—	—
Pellet durability index, %								
Standard	83.5	84.1	84.0	82.1	.5	—	.11	.03
Modified[b]	78	79.4	79.4	77.0	.6	—	—	.04
Fines, %	9.9	8.6	9.2	11.0	.85	—	—	—

[a]Expressed as the difference between full load and empty load.
[b]Am. Society of Ag. Eng. S269.3 with the addition of five ½ in. hexagonal nuts.
[c]Contrast were: 1) corn vs sorghums; 2) mill-run sorghum vs red and white; 3) red vs white.
[d]Dashes indicate P>.15.

Table 3. Effects of Different Sorghum Varieties on Growth Performance in Nursery Pigs[a]

	Treatment					Contrast[b]		
Item	Corn	Mill-Run Sorg	Red Sorg	White Sorg	SE	1	2	3
d 0 to 7								
ADG, lb	.61	.55	.60	.54	.02	.02	—[c]	.03
ADFI, lb	.57	.56	.59	.55	.02	—	—	.13
F/G	.93	1.02	.98	1.02	.06	.04	—	—
d 7 to 21								
ADG, lb	.98	1.03	1.07	1.09	.03	.05	—	—
ADFI, lb	1.21	1.28	1.29	1.26	.04	—	—	—
F/G	1.23	1.24	1.21	1.16	.04	—	.05	—
d 21 to 35								
ADG, lb	1.39	1.46	1.43	1.40	.03	—	—	—
ADFI, lb	1.81	1.88	1.87	1.79	.06	—	—	—
F/G	1.30	1.29	1.31	1.28	.05	—	—	—
d 0 to 35								
ADG, lb	1.07	1.11	1.12	1.10	.02	.13	—	—
ADFI, lb	1.32	1.38	1.38	1.33	.03	—	—	—
F/G	1.23	1.24	1.23	1.21	.03	—	—	—
Digestibility, %								
Dry matter	86.3	80.8	85.3	86.9	.2	—	—	.001
Nitrogen	81.7	80.8	78.0	82.9	.5	.06	—	.001
Gross energy	88.5	88.2	87.2	88.6	.2	.04	—	.001

[a]A total of 192 pigs (6 pigs/pen and 8 pens/treatment) with an average initial BW of 15 lb and an average age of 21 d.
[b]Contrasts were: 1) corn vs sorghums; 2) mill-run sorghum vs red and white sorghums; 3) red vs white sorghum.
[c]Dashes indicate P>.15.

INFLUENCE OF DRY, EXTRUDED-EXPELLED SOYBEAN MEAL FROM DIFFERENT MANUFACTURERS ON GROWTH PERFORMANCE OF NURSERY PIGS [1]

J. C. Woodworth, J. M. DeRouchey, M. D. Tokach, J. L. Nelssen, R. D. Goodband, and M. U. Steidinger

Summary

A total of 150 pigs (initially 22 lb; 42 d of age) was used to determine the influence of dry, extruded-expelled soybean meal from three different manufacturers on growth performance of pigs. No differences were observed for ADG, ADFI, or F/G between any of the sources. All three sources resulted in performance similar to that with a corn-soybean meal diet with added fat. These results confirm the accuracy of the energy values published in the 1998 Swine Day Report for dry, extruded-expelled soybean meal.

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

Introduction

Extrusion processing followed by expelling is a relatively recent technology developed for soybean meal processing. The extruder-expeller process (Insta-Pro Express™ extruder/press system) results in a product that has a higher fat content and improved amino acid digestibility compared to solvent-extracted soybean meal. In previous trials conducted at Kansas State University (1998 Swine Day Report), pigs fed diets containing extruded-expelled soybean meal had similar growth performance as pigs fed diets containing conventional soybean meal and soy oil when diets were formulated on an equal lysine and energy basis. In that trial, a research plant processed the extruded-expelled soybean meal. However, the dry matter content and protein concentration of the soybean meal can vary considerably among commercial plants. Therefore, this experiment was designed to compare the influence of dry, extruded-expelled soybean meal from three different commercial manufacturers on growth performance of nursery pigs.

Procedures

A total of 150 pigs (initially 22 lb and 42 d of age) was used in a 15 d growth trial. Pigs (PIC, C-22 barrows) were blocked by initial weight and randomly allotted to one of five dietary treatments with five pigs per pen and six pens per treatment. Experimental treatments (Table 1) included a negative control diet containing conventionally processed soybean meal (46.5% crude protein, CP) formulated to 1.10% total lysine and 1.48 Mcal ME/lb, three diets (1.14% lysine and 1.55 Mcal ME/lb) containing dry, extruded-expelled soybean meal from one of three different manufacturers that were formulated to the same lysine:metabolizable energy ratio as the negative control diet, and a positive control diet containing the conventionally processed soybean meal and 3.29% soy oil formulated to the same total lysine and metabolizable energy concentrations as the diets containing the extruded-expelled meals. Nutrient profiles for the conventionally processed soybean meal and soy oil were from the 1998 Swine NRC, and profiles for the dry, extruded-expelled soybean meal

[1]Appreciation is expressed to Bruning Grain and Feed Co., Inc., Bruning, NE; Klepper Oil, Dubois, NE; and North Central Kansas Processors, Washington, KS for use of their soybean meal products.

were from the previous research published in the 1998 KSU Swine Day Report. All dry, extruded-expelled soybean meal sources were processed by the Insta-Pro Express™ extruder/press system.

Pigs were housed in an environmentally controlled nursery at the KSU 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 water and feed. Pigs were weighed and feed disappearance was determined on d 0, 7, and 15 to determine ADG, ADFI, and feed efficiency (F/G).

Data were analyzed as a randomized complete block design with pen as the experimental unit using the GLM procedure of SAS. Orthogonal contrasts were used to compare the growth performance of pigs fed diets containing 1) 46.5% CP soybean meal and no oil to the other diets, 2) dry, extruded-expelled soybean meal to the diet containing 46.5% CP soybean meal and soy oil, and 3) only 46.5% CP soybean meal without oil to the diet containing 46.5% CP soybean meal and soy oil.

Results and Discussion

For the entire trial, ADG was not influenced (P>.10; Table 2) by dietary treatment. No differences in growth performance occurred among pigs fed diets containing any of the dry, extruded-expelled soybean meal sources (P>.10). Pigs fed the negative control diet containing only 46.5% CP soybean meal had higher (P<.01) ADFI and poorer F/G compared to pigs fed other diets.

These data suggest that dry, extruded-expelled soybean meal from different commercial manufacturers elicits similar growth performance from nursery pigs. This confirms the benefits (improved feed efficiency with similar ADG) of the higher energy content of the dry, extruded-expelled soybean meal compared to conventionally processed soybean meal. Consequently, a higher price can be paid for the dry, extruded-expelled soybean meal to reflect the higher energy concentration. The economic feasibility of using dry, extruded-expelled soybean meal to replace conventional soybean meal was reported in the 1998 KSU Swine Day Report and was calculated as a relationship with conventional soybean meal and fat prices.

One advantage of processing soybeans with the Insta-Pro Express™ extruder/press system is that the resultant extruded-expelled soybean meal commonly has a greater dry matter content than conventionally processed soybean meal. Because of this, some manufacturers add water to match the dry matter contents between the two products. The addition of water could negatively influence the nutrient concentrations and the quality of the soybean meal product and, thus, affect the growth performance of pigs fed the product. Consequently, it is important to know the dry matter content when comparing soybean meal sources. The manufacturers represented in this experiment did not add water to their products.

In conclusion, diets containing dry, extruded-expelled soybean meal can replace diets containing conventionally processed soybean meal and soy oil for swine. Dry, extruded-expelled soybean meal from the commercial manufacturers represented in this trial influenced growth similarly. Economics and availability will dictate which soybean meal source to use.

Table 1. Compositions of Experimental Diets (As-Fed Basis)

Ingredient, %	46.5% CP SBM	Dry, Extruded-Expelled SBM	46.5% CP SBM + Oil
Corn	65.40	62.78	60.37
46.5% CP SBM	30.39	-	32.13
Dry, extruded-expelled SBM[a]	-	32.99	-
Soy oil	-	-	3.29
Monocalcium phosphate	1.46	1.51	1.47
Limestone	1.00	.97	.99
Medication	1.00	1.00	1.00
Salt	.35	.35	.35
Vitamin premix	.25	.25	.25
Trace mineral premix	.15	.15	.15
Calculated analysis			
CP, %	19.82	21.14	20.19
Lysine, total, %	1.10	1.14	1.14
Methionine, total, %	.31	.32	.32
ME, Mcal/lb	1.48	1.55	1.55
Lys:ME, g/Mcal	3.31	3.31	3.31
Ca, %	.75	.75	.75
P, %	.70	.70	.70

[a]Dry, extruded-expelled soybean meal was from one of three different commercial manufacturers.

Table 2. Influence of Dry, Extruded-Expelled Soybean Meal from Different Processors on Growth Performance of Pigs[a]

	46.5% CP	Dry, Extruded-Expelled SBM			46.5% CP		Contrast, P<[b]		
Item	SBM	Source 1	Source 2	Source 3	SBM + Oil	SEM	1	2	3
Day 0 to 15									
ADG, lb	1.18	1.18	1.17	1.19	1.23	.035	.76	.24	.34
ADFI, lb	1.93	1.74	1.78	1.67	1.81	.053	.005	.22	.10
F/G	1.65	1.47	1.52	1.40	1.47	.055	.007	.99	.03

[a]Values are the means of 150 pigs (initially 22 lb) with five pigs per pen and six pens per treatment.

[b]Contrasts were 1) 46.5% CP SBM vs others, 2) Source 1, 2, 3 vs 46.5% CP SBM + oil, and 3) 46.5% CP SBM vs 46.5% CP SBM + oil.

THE pH OF SPRAY-DRIED BLOOD MEAL DOES NOT INFLUENCE NURSERY PIG PERFORMANCE [1,2]

J. M. DeRouchey, J. L. Nelssen, M. D. Tokach, R. D. Goodband, S. S. Dritz[3], J. C. Woodworth, B. W. James, M. J. Webster, and D. E. Real

Summary

Two studies were conducted to evaluate the effects of spray-dried blood meal and its pH on nursery pig performance. Spray-dried blood meal pH decreases as storage time increases prior to spray drying. In Exp. 1, addition of 2.5% spray-dried blood meal to the diet improved ADG and ADFI in nursery pigs (15.4 lb to 35.9 lb), but did not influence feed efficiency. In Exp. 2, the inclusion of 5% spray-dried blood meal improved feed efficiency without affecting ADG or ADFI. The pH (7.4 to 5.9 in Exp. 1 and 7.6 to 5.9 in Exp. 2) of the blood meal did not influence growth performance.

(Key Words: Nursery Pig, Blood Meal, Growth.)

Introduction

Spray-dried blood meal is an animal protein product that is used to enhance nursery pig performance. However, the degradation of, or alterations in, the composition of blood meal from processing or prolonged storage may affect quality. Decomposition of blood meal prior to spray drying has been associated with an increase in volatile biological nitrogen (VBN), which decreases the pH of the blood meal. This decrease in pH is believed to increase the offensiveness of the blood meal's odor, which may have a negative effect on palatability. Thus, the objective of this experiment was to determine the effects of pH level of blood meal on growth performance in nursery pigs.

Procedures

Experiment 1. A total of 240 pigs (BW of 11.2 lb and 17 ± 2 d of age) was used in a 31-d growth assay. Pigs were blocked by weight and allotted to one of five dietary treatments with eight pigs/pen and six pens/treatment. Pigs were housed in an environmentally controlled nursery in 5 × 5 ft pens on a commercial farm in northeast Kansas. All pens contained one self-feeder and two nipple waterers to provide ad libitum access to feed and water.

All pigs were fed the same pelleted, segregated early weaning (SEW) and transition diets (Table 1) to d 10 after weaning. Then they were fed dietary treatments, which included a control diet with no added blood meal and four diets containing 2.5% blood meal. The four blood meals were from the same spray-drying processing facility, but had pHs of 7.4, 6.7, 6.4, and 5.9 at the time of spray drying. The first three originated from beef blood, whereas the blood meal of pH 5.9 was of poultry origin. The length of time between collection of the blood from the slaughter facility and drying was not available. Treatment diets were fed in meal form and formulated to contain 1.35% lysine, .82 Ca, and .48 available P (Table 2).

[1]Appreciation is expressed to Jerry Ball of California Spray Dry Company, Stockton, CA, for partial financial support.

[2]The authors thank Eichman Brothers and Ken Anderson, St. George, KS, for the use of facilities and pigs for Exp. 1.

[3]Food Animal Health and Management Center.

Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 10 after weaning, then each 7 d for the remainder of the trial.

Experiment 2. A total of 150 pigs (BW of 13.8 and 17 ± 2 d of age) was used in a 19-d growth assay. Pigs were blocked by weight and allotted to one of five dietary treatments, with five pigs/pen and six pens/ treatment. Pigs were housed in the Kansas State University Segregated Early Weaning Facility. Each pen was 4 × 4 ft and contained one self-feeder and one nipple waterer to provide ad libitum access to feed and water. The initial temperature was 90°F for the first 5 d and was lowered approximately 3°F each week thereafter.

All pigs were fed the same pelleted SEW diet (Table 1) to 5 d after weaning. Then they were fed experimental diets, which included a control diet with no added blood meal and four diets containing 5.0% blood meal. The four blood meals were spray-dried from the same lot of blood from a beef slaughter facility. One fourth of the total lot was dried on d 0, 3, 8, and 12 after collection. This drying schedule resulted in blood meals with pH values of 7.6, 6.4, 6.0, and 5.9, respectively. Treatment diets were fed in meal form; formulated to contain 1.40% lysine, .90 Ca, and .54 available P; and balanced for Na and Cl concentrations (Table 2). In addition, we added crystalline amino acids to the diets containing spray dried blood meal to maintain similar ratios of amino acids to lysine compared to the control diet. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 5, 12, and 19 after weaning. Furthermore, spray-dried blood meal samples were obtained for analysis to determine bacterial concentrations within each lot.

Data from both experiments were analyzed as a randomized complete block design with pen as the experimental unit. Pigs were blocked based on weaning weight, and analysis of variance was performed using the GLM procedure of SAS. Linear, quadratic, and cubic polynomial contrasts for unequally spaced treatments were used to determine the effects of decreasing blood meal pH. Initial pig weight at the start of the experimental period was used as a covariate for statistical analysis.

Results and Discussion

Experiment 1. When pigs were fed the common diets from d 0 to 10 after weaning, ADG, ADFI, and F/G were .41 lb, .43 lb and 1.05, respectively. Adding 2.5% blood meal to the diet numerically increased ADG ($P>.10$) during all 3 weeks of the experiment. Pigs fed added dietary spray-dried blood meal had greater ($P<.02$) ADG for the overall trail. The addition of blood meal increased ($P<.03$) ADFI from d 7 to 14, d 14 to 21 , and for the overall trial. Feed efficiency was not influenced by the addition of blood meal to the diet.

The pH level of the blood meal did not influence pig performance during the experiment.

Experiment 2. When pigs were fed the common diets from d 0 to 5 after weaning, ADG, ADFI, and F/G were .24 lb, .23 lb, and .96, respectively. The inclusion of 5.0% spray-dried blood meal did not influence ADG or ADFI. However, the response to spray-dried blood meal was similar to that in Exp. 1 for the same time period, with a numerical trend ($P>.10$) for an increase in ADG. Efficiency of growth was improved from d 7 to 14 ($P<.02$) and overall ($P<.004$) in pigs fed spray-dried blood meal. In addition, no significant effects of blood meal pH were detected. However, an overall numerical decrease in ADFI was observed for the lowest blood meal pH level. This indicates that storing whole blood for 12 d before spray drying may begin to result in decreased food intake. However, this may be a function of some other change during predrying storage time rather then pH level, because the identical pH level in Exp. 1 did not elicit this same response.

The concentration of bacteria (Table 5) rose as storage time increased until d 8 (pH level of 6.0) and then declined slightly at d

12 of spray-drying (pH level of 5.9). No coliforms were detected in any of the blood meal lots. In addition, the greatest reduction in blood meal pH was seen when blood was stored for 8 d, and changes were minimal with further storage. The bacterial level in the blood meal did not appear to influence the growth performance in this trial.

In conclusion, data from this trial and others indicate that spray-dried blood meal addition in nursery diets improves growth performance. Furthermore, the pH of blood meal (7.6 to 5.9) did not affect nursery pig performance in these experiments. Thus, pH is not a reliable quality parameter that is predictive of growth performance.

Table 1. Compositions of Common Diets (Exps. 1 and 2)[a]

Ingredient, %	Segregated Early Weaning	Transition
Corn	33.37	39.81
Spray-dried whey	25.00	20.00
Soybean meal (46.5%)	12.80	23.30
Spray-dried animal plasma	6.70	2.50
Select menhaden fish meal	6.00	2.50
Choice white grease	6.00	5.00
Lactose	5.00	—
Spray-dried blood cells	1.65	2.50
Medication[b]	1.00	1.00
Monocalcium phosphate (21% P)	.75	1.30
Limestone	.45	.73
Zinc oxide	.38	.38
Vitamin premix	.25	.25
Salt	.20	.30
Trace mineral premix	.15	.15
L-Lysine HCl	.15	.15
DL-Methionine	.15	.13
Total	100.00	100.00
Calculated Analysis		
Lysine, %	1.70	1.60
Met:lysine ratio, %	30	30
Met & Cys:lysine ratio,%	57	57
Threonine:lysine ratio, %	65	65
Tryptophan:lysine ratio, %	18	19
ME, kcal/lb	1,595	1,559
Protein, %	22.4	22.5
Calcium, %	.90	.90
Phosphorus, %	.80	.80
Available phosphorus, %	.66	.59
Lysine:calorie ratio, g/Mcal ME	4.83	4.66

[a]In Exp.1, 1 lb per head of SEW diet was fed, then pigs were fed the transition diet for the remainder of the 10 d period. For Exp. 2, pigs consumed SEW diet for 5 d, then were fed the experimental diets.

[b]Provided 50 g per ton carbadox.

Table 2. Compositions of Experimental Diets (Exps. 1 and 2)

	Exp. 1[a]		Exp. 2[b]	
Ingredient, %	No Blood Meal	Added Blood Meal	No Blood Meal	Added Blood Meal
Corn	46.51	51.38	45.68	53.62
Soybean meal (46.5%)	33.82	26.35	39.45	26.43
Spray-dried whey	10.00	10.00	10.00	10.00
Choice white grease	5.00	5.00	—	—
Spray-dried blood meal	—	2.50	—	5.00
Monocalcium phosphate (21% P)	1.60	1.60	1.84	1.86
Medication[c]	1.00	1.00	1.00	1.00
Limestone	.85	.90	.82	.79
Salt	.35	.35	.36	.30
Vitamin premix	.25	.25	.25	.25
Zinc oxide	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15
Calcium chloride	—	—	.11	.18
L-Lysine HCl	.15	.15	—	—
DL-Methionine	.07	.12	.08	.13
L-Threonine	—	—	.01	.03
L-Isoleucine	—	—	—	.01
Total	100.00	100.00	100.00	100.00
Calculated Analysis				
Lysine, %	1.35	1.35	1.40	1.40
Met:lysine ratio, %	32	29	31	33
Met & Cys:lysine ratio,%	56	56	60	60
Isoleucine:lysine ratio, %	67	56	67	67
Threonine:lysine ratio, %	59	62	74	60
Tryptophan:lysine ratio, %	19	20	22	21
ME, kcal/lb	1,559	1,565	1,458	1,449
Calcium, %	.82	.82	.90	.90
Phosphorus, %	.74	.77	.86	.81
Available phosphorus, %	.48	.48	.54	.54
Sodium, %	.26	.29	.26	.26
Chloride, %	.42	.46	.43	.43

[a]Diets fed from 10 d until 31 d postweaning.

[b]Diets fed from 5 d until 19 d postweaning.

[c]Provided 50 g per ton carbadox.

Table 3. Effects of Spray-Dried Blood Meal pH on Growth Performance in Phase II Nursery Pigs (Exp. 1)[a,b]

		Blood Meal pH					Probability
Item	No Blood Meal	7.4	6.7	6.4	5.9	SE	No Blood Meal vs Others[c]
Initial weight, lb[d]	15.59	15.13	15.69	15.10	15.38	.20	.24
Day 0 to 7							
ADG, lb	.61	.62	.63	.68	.66	.04	.28
ADFI, lb	.93	.93	.97	1.02	.98	.04	.27
F/G	1.52	1.50	1.54	1.50	1.48	.05	.91
Day 7 to 14							
ADG, lb	.94	1.03	1.02	.99	.98	.04	.16
ADFI, lb	1.38	1.47	1.48	1.46	1.48	.03	.02
F/G	1.47	1.43	1.45	1.47	1.51	.05	.91
Day 14 to 21							
ADG, lb	1.28	1.32	1.31	1.30	1.36	.03	.28
ADFI, lb	1.82	1.93	1.92	1.97	1.96	.05	.03
F/G	1.42	1.46	1.47	1.52	1.44	.04	.19
Day 0 to 21							
ADG, lb	.95	.99	.97	.99	1.00	.01	.02
ADFI, lb	1.38	1.44	1.46	1.48	1.47	.03	.02
F/G	1.45	1.45	1.51	1.49	1.47	.03	.35
Final weight, lb	35.07	36.32	35.73	35.96	36.33	.35	.02

[a]A total of 240 pigs (eight pigs per pen and six pens per treatment) with an average initial BW of 15.4 lbs. at the beginning of phase II. All pigs were fed common SEW and transition diets for the first 10 days. Thus, d 0 of the experiment is actually 10 days after weaning.

[b]Growth performance for the first 10 d after weaning was: ADG = .41 lb, ADFI = .43 lb, and F/G = 1.05.

[c]No blood meal pH effects, P>.10.

[d]Initial pig weight (d 10 postweaning) was used as a covariate in the statistical analysis of growth performance.

Table 4. Effects of Blood Meal pH on Growth Performance in Weanling Pigs (Exp. 2)[a,b]

		Blood Meal pH					Probability
Item	No Blood Meal	7.6	6.9	6.0	5.9	SE	No Blood Meal vs Others[c]
Initial weight, lb[d]	14.66	15.11	14.92	15.00	15.16	.18	.08
d 0 to 7							
ADG, lb	.30	.34	.31	.33	.31	.04	.62
ADFI, lb	.68	.64	.68	.65	.58	.04	.32
F/G	2.27	1.88	2.19	1.96	1.87	.38	.15
d 7 to 14							
ADG, lb	.63	.74	.71	.74	.69	.05	.13
ADFI, lb	.89	.94	.83	.89	.86	.06	.87
F/G	1.41	1.27	1.17	1.20	1.25	.06	.02
d 0 to 14							
ADG, lb	.47	.54	.51	.54	.50	.04	.18
ADFI, lb	.78	.79	.76	.77	.72	.04	.56
F/G	1.66	1.46	1.49	1.42	1.44	.06	.004

[a]A total of 180 pigs (five pigs per pen and six pens per treatment) with an average initial BW of 14.95 lb at the beginning of phase II. All pigs were fed a common SEW diet for the first 5 days. Thus, d 0 of the experiment is actually 5 d after weaning.

[b]Growth performance for the first 5 d after weaning was: ADG = .24 lb, ADFI = .23 lb, and F/G = .96.

[c]No blood meal pH effects, P>.15.

[d]Initial pig weight (d 5 postweaning) was used as a covariate in the statistical analysis of growth performance.

Table 5. Effect of Blood Meal pH on Bacterial Concentration (Exp. 2)

	Blood Meal pH			
Item	7.6	6.9	6.0	5.9
Total Plate Count	3.7×106	1.1×10^7	1.2×107	6.6×106
Total Coliform Count	0	0	0	0

EFFECTS OF IRRADIATION OF SPRAY-DRIED BLOOD MEAL AND ANIMAL PLASMA ON NURSERY PIG GROWTH PERFORMANCE

J. M. DeRouchey, M. D. Tokach, J. L. Nelssen, R. D. Goodband, S. S. Dritz[1], B. W. James, and M. J. Webster

Summary

Two trials were conducted to determine the effects of irradiation of spray-dried blood meal and animal plasma on nursery pig growth performance. In Exp. 1, irradiation of spray-dried blood meal resulted in improved ADG and F/G and tended to increase ADFI for the 14 d experiment. The majority of the increase in growth performance occurred during the first week of the trial. In Exp. 2, ADG and ADFI were increased from d 0 to 10 for pigs fed irradiated spray-dried animal plasma compared to pigs fed regular spray-dried animal plasma. In addition, we observed differences in growth performance between different sources of spray-dried plasma used in this experiment.

(Key Words: Nursery Pig, Irradiation, Blood Meal, Animal Plasma.)

Introduction

Research shows that the inclusion of spray-dried blood products to nursery diets improves growth performance. However, different manufacturers of blood by-products utilize various types of drying and processing techniques. Past research at Kansas State University has shown a large amount of variation in spray-dried blood products within and between manufacturers. Most blood products that are commercially available are spray-dried. That processing method exposes the product to heat, which may decrease protein quality. Irradiation processing of these blood products may cause a decrease in antinutritional factors or cause structural changes within the protein, aiding in digestibility of the blood products. Therefore, our objective was to determine the effects of irradiation processing of different blood products on nursery pig growth performance.

Procedures

Experiment 1. This experiment was conducted in conjunction with an experiment to determine the impact of pH of blood meal on pig performance reported in the previous article. A total of 60 pigs (BW of 13.8 and 17 ± 2 d of age) was used in a 19-d growth assay. Pigs were blocked by weight and allotted to one of two dietary treatments. There were five pigs/pen and six pens/treatment. Pigs were housed in the Kansas State University Segregated Early Weaning Facility. Each pen was 4 × 4 ft and contained one self-feeder and one nipple waters to provide ad libitum access to feed and water. Initial temperature was 90°F for the first 5 d and was lowered approximately 3°F each week thereafter.

All pigs were fed the same pelleted SEW diet (Table 1) to 5 d postweaning. Then the pigs were switched to experimental diets containing 5% spray-dried blood meal or spray-dried blood meal that had been irradiated. All blood meal originated from the same lot. The spray-dried blood meal was irradiated at an average dose of 9.54 kGy (24 doses with a 7.2 kGy minimum and 11.8 kGy maximum dose).

Treatment diets were fed in meal form and formulated to contain 1.40% lysine, .90 Ca, and .54 available P. Diets also were balanced for Na and Cl concentrations (Table 1). Average daily gain, ADFI, and F/G were

[1]Food Animal Health and Management Center.

determined by weighing pigs and measuring feed disappearance on d 5 after weaning and on d 7 and 14 (d 12 and 19 after weaning) of the treatment period. Blood meal samples were taken for analysis to determine bacterial concentrations prior to manufacturing of the complete diet.

Experiment 2. A total of 180 pigs (BW of 13.1 lb and 17 ± 2 d of age) was used in a 24 d growth assay to determine the effects of source, processing technique, and irradiation of spray-dried animal plasma on nursery pig performance. There were five pigs/pen and six pens/treatment. Pigs were housed in an environmentally controlled nursery in 5 × 5 ft pens located at the Kansas State University Swine Teaching and Research Center. All pens contained one self-feeder and nipple water to provide ad libitum access to feed and water.

Treatment diets were fed in meal form from d 0 to 10, and included a control diet containing no animal plasma and five additional diets containing 5 % spray-dried animal plasma from two different sources and processing techniques. From source 1, treatment diets consisted of plasma that had been spray-dried, spray-dried then irradiated, or freeze dried then irradiated. From source 2, treatment diets consisted of plasma that had been spray-dried or spray-dried then irradiated. The spray-dried animal plasma was irradiated at an average dose of 9.75 kGy (8 doses with a 9.50 kGy minimum and 10.00 kGy maximum dose). All treatment diets were formulated to contain 1.50% lysine, .89 Ca, and .54 available P. Diets also were balanced for Na and Cl concentrations (Table 1). A common Phase II diet was fed from d 10 to 24 (Table 1). The ADG, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 5, 10, and 24 after weaning. Spray-dried animal plasma samples were taken prior to manufacturing of the complete diet, and feed samples were obtained at the initiation of the experiment for analysis to determine bacterial concentrations within each treatment.

Results and Discussion

Experiment 1. From d 0 to 7, pigs fed irradiated spray-dried blood meal had improved (P<.03) ADG and ADFI and tended (P<.13) to have improved feed efficiency (Table 2). From d 7 to 14, both ADG and F/G (P<.09) improved moderately with irradiated spray-dried blood meal, but ADFI was not affected. For the entire treatment period, pigs fed irradiated spray-dried blood meal had improved (P<.02) ADG and F/G and showed a tendency to increase food intake (P<.13). Irradiation of the spray-dried blood meal reduced the bacterial concentration from 6.6×10^6 to 9.0×10^1.

Experiment 2. From d 0 to 5, pigs fed irradiated spray-dried animal plasma had increased ADG (P<.05) and ADFI (P<.10) compared to those fed regular spray-dried animal plasma, regardless of source (Table 3). In addition, pigs fed source two nonirradiated plasma had improved ADG and F/G (P<.05) compared to those fed the control diet, whereas those fed spray-dried animal plasma source one did not. From d 5 to 10, pigs fed spray-dried animal plasma source 2 plasma had increased ADG and ADFI (P<.05) compared with the control diet without spray-dried animal plasma. For d 0 to 10, ADG (P<.05) and ADFI (P<.10) was greater for pigs fed irradiated spray-dried animal plasma versus animal plasma that was not irradiated. Freeze-dried and irradiated plasma did not improve growth performance compared to plasma from the same source that had been spray-dried then irradiated.

From d 10 to 24, ADFI was improved (P<.05) for pigs previously fed diets containing spray-dried animal plasma that was irradiated versus spray-dried animal plasma that was not. In addition, pigs fed irradiated spray-dried animal plasma were heavier (P<.05) at the conclusion of the trial compared to those fed the control diet, whereas pigs on the treatment diets with regular spray-dried plasma were not.

Irradiation reduced the bacterial concentration in the spray-dried animal plasma, regardless of source (Table 3). In addition,

this proved to be beneficial in reducing the total bacteria load in the whole diet. However, the counts indicated that a lot of bacteria exist in other feed ingredients of the nursery diets.

In conclusion, irradiation of spray-dried blood meal and animal plasma improved growth performance. Whether the response to irradiated blood products was from a reduction in total bacterial concentration, an increase in digestibility of the protein portion, or another reason is unclear and needs to be investigated further. Freeze-dried then irradiated plasma showed no advantage over spray-dried then irradiated plasma, indicating that protein damage from heat occurring during the spray-drying process is not a concern and that freeze-drying offers no further benefits. Furthermore, differences between sources of spray-dried animal plasma were evident in our study.

Table 1. Compositions of Common and Experimental Diets (Exps. 1 & 2)

	Common		Exp. 1	Exp. 2	
Ingredient, %	SEW[a]	Phase II[b]	Blood Meal	No Plasma	Added Plasma
Corn	33.37	48.83	53.62	41.88	49.39
Soybean meal (46.5%)	12.80	29.00	26.43	37.68	25.71
Spray-dried whey	25.00	10.00	10.00	15.00	15.00
Lactose	5.00	-	-	-	-
Spray-dried animal plasma	6.70	-	-	-	5.00
Spray-dried blood meal	-	-	5.00	-	-
Spray-dried blood cells	1.65	2.50	-	-	-
Select menhaden fish meal	6.00	-	-	-	-
Choice white grease	5.00	-	-	-	-
Medication[c]	1.00	1.00	1.00	1.00	1.00
Monocalcium P (21% P)	.75	1.85	1.86	1.49	1.38
Limestone	.45	.95	.79	1.02	1.15
Salt	.20	.25	.30	.42	.30
Calcium chloride	-	-	.18	-	-
Sodium bicarbonate	-	-	-	.38	-
Zinc oxide	.38	-	.25	.39	.39
Vitamin premix	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15
L-Lysine HCl	.15	.15	-	.15	.15
DL-Methionine	.15	.07	.13	.16	.13
L-Threonine	-	-	.03	.03	-
L-Isoleucine	-	-	.01	-	-
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
Lysine, %	1.70	1.40	1.40	1.50	1.50
Met:lysine ratio, %	30	28	33	34	30
Met & Cys:lysine ratio,%	57	55	60	60	60
Threonine:lysine ratio, %	65	65	67	64	64
Tryptophan:lysine ratio, %	18	20	21	20	19
ME, kcal/lb	1,595	1570	1449	1447	1468
Calcium, %	.90	.89	.90	.90	.90
Phosphorus, %	.80	.80	.81	.80	.80
Available phosphorus, %	.66	.54	.54	.50	.46
Sodium, %	.42	.23	.26	.43	.43
Chloride, %	.45	.39	.43	.53	.53

[a]Diet fed from d 0 to 5 after weaning in Exp. 1. [b]Diet fed from d 10 to 24 after weaning in Exp.2.
[c]Provided 50 g per ton carbadox.

Table 2. Effects of Irradiated Spray-Dried Blood Meal on Growth Performance of Nursery Pigs and Bacterial Concentrations [a]

	Blood Meal			
Item	Regular	Irradiated[b]	SE	Probability[c]
Initial weight, lb	15.16	14.82	.18	.21
d 0 to 7				
ADG, lb	.31	.43	.04	.03
ADFI, lb	.58	.69	.04	.03
F/G	1.87	1.60	.05	.13
d 7 to 14				
ADG, lb	.69	.82	.05	.09
ADFI, lb	.86	.92	.06	.46
F/G	1.25	1.12	.04	.09
d 0 to 14				
ADG, lb	.50	.62	.04	.02
ADFI, lb	.72	.80	.04	.13
F/G	1.44	1.29	.03	.02
Blood meal[d]				
Total plate count	6.6×10^6	9.0×10^1	—	—
Total coliform count	0	0	—	—

[a]A total of 60 pigs (five pigs per pen and six pens per treatment) with an average initial BW of 14.95 lb at the beginning of phase II. All pigs were fed a common SEW diet for the first 5 days. Thus, d 0 of the experiment is actually 5 d after weaning. Growth performance for the first 5 d after weaning was: ADG, .24 lb; ADFI, .23 lb; and F/G, .96.

[b]Irradiated at an average dose of 9.54 kGy (24 doses with a 7.2 kGy minimum and 11.8 kGy maximum dose).

[c]Initial pig weight (d 5 postweaning) was used as a covariate in the growth performance statistical analysis.

[d]Samples obtained prior to manufacturing of complete diet.

Table 3. Effects of Source, Processing Technique, and Irradiation of Plasma on Weanling Pig Growth Performance and Bacterial Concentrations[a]

		Plasma Source 1			Plasma Source 2		
Item	No Plasma Control	Spray-Dried	Spray-Dried and Irradiated	Freeze-Dried and Irradiated	Spray-Dried	Spray-Dried and Irradiated	SEM
Initial wt, lb	13.10	13.09	13.07	13.09	13.02	13.10	
D 0 to 5							
ADG, lb[bd]	.49[f]	.49[f]	.62[g]	.60[g]	.59[g]	.71[h]	.03
ADFI, lb[e]	.46[f]	.47[f]	.52[f]	.48[f]	.47[f]	.62[g]	.04
F/G[c]	.94[f]	.96[f]	.84[fg]	.80[g]	.80[g]	.87[fg]	.05
D 5 to 10							
ADG, lb[b]	.56[f]	.62[fg]	.69[fg]	.67[fg]	.71[g]	.75[g]	.05
ADFI, lb[b]	.77[f]	.82[fg]	.91[fg]	.87[fg]	.97[g]	.98[g]	.05
F/G	1.38	1.32	1.32	1.30	1.37	1.31	.08
D 0 to 10							
ADG, lb[bd]	.53[f]	.56[fg]	.66[hi]	.64[gh]	.65[hi]	.73[i]	.03
ADFI, lb[be]	.62[f]	.65[f]	.72[fg]	.68[f]	.72[fg]	.80[g]	.04
F/G	1.17	1.16	1.09	1.06	1.11	1.10	.03
Pig wt, lb							
D 10[bd]	18.39[f]	18.60[fg]	19.62[hi]	19.45[gh]	19.51[hi]	20.37[hi]	.32
D 10 to 24							
ADG, lb	.88[f]	.88[f]	.89[f]	.76[g]	.79[g]	.82[fg]	.03
ADFI, lb[d]	1.08[fg]	1.00[f]	1.12[g]	.99[f]	.99[f]	1.06[fg]	.03
F/G	1.23[f]	1.14[g]	1.26[f]	1.30[f]	1.25[f]	1.29[f]	.04
Pig wt, lb							
D 24[be]	28.11[f]	29.71[fg]	31.27[g]	29.49[fg]	29.92[fg]	31.31[g]	.77
Spray-dried animal plasma[j]							
Total plate count	N/A	9.0×10^4	4.5×10^1	0	2.6×10^4	3.5×10^2	—
Total coliform count	N/A	0	0	0	0	0	—
Whole diet[k]							
Total plate count	3.7×10^4	1.0×10^4	3.1×10^2	6.8×10^3	1.0×10^4	7.6×10^3	—
Total coliform count	2.8×10^4	6.7×10^3	3.0×10^2	2.1×10^2	6.0×10^3	1.0×10^3	—

[a]A total of 180 pigs (five pigs per pen and six pens per treatment) with an average initial BW of 13.1 lb. [b]Control vs mean of plasma trts (P<.05). [c]Control vs mean of plasma trts (P<.10). [d]Spray-dried plasma vs spray-dried and irradiated plasma (P<.05). [e]Spray-dried plasma vs spray-dried and irradiated plasma (P<.10). [fghi]Means in same row with superscripts differ (P<.05). [j]Samples obtained prior to manufacturing of complete feed. [k]Samples obtained at initiation of the feeding experiment.

EFFECTS OF GAMMA RAY AND ELECTRON BEAM IRRADIATION LEVELS IN SPRAY-DRIED BLOOD MEAL ON NURSERY PIG PERFORMANCE

J. M. DeRouchey, J. L. Nelssen, M. D. Tokach, R. D. Goodband, S. S. Dritz[1], J. C. Woodworth, M. J. Webster, B. J. James, and D. E. Real

Summary

Three hundred weanling pigs (initially 23.7 lbs and 17 ± 6 d of age) were used in a 19-d growth assay to determine the effects of increasing levels (2.5, 5.0, and 10.0, and 20.0 kGy) of gamma ray and electron beam irradiation of spray-dried blood meal on growth performance. Irradiation of blood meal resulted in decreased concentrations of aerobic bacteria, *E. coli*, mold, and yeast in spray-dried blood meal. The inclusion of irradiated spray-dried blood meal tended to improve F/G from d 0 to 7 and for the overall trial (d 0 to 14), but had no effects on ADG or ADFI. Comparison of the two types of irradiation and dosage level showed no differences in growth performance. In this experiment, the inclusion of spray-dried blood meal did not improve growth performance over that obtained with the control diet.

(Key Words: Nursery Pig, Blood Meal, Irradiation.)

Introduction

Recent research at Kansas State University showed improvements in growth performance of nursery pigs consuming blood products that have undergone irradiation treatment. However, different methods and dosage levels of irradiation are available. Irradiation involves exposing a given substance to ionizing energy to create ions and free radicals. The result of this energy is the destruction of living microorganisms. Also, antinutritional factors can be broken down with an increase in dosage level. Therefore, our objective was to determine the effects of increasing levels (2.5, 5.0, 10.0, and 20.0 kGy) of gamma ray (cobalt-60 source) and electron beam irradiation of spray-dried blood meal on growth performance of weanling pigs.

Procedures

A total of 300 pigs (BW of 23.6 and 17 ± 6 d of age) was used in a 19-d growth assay. Pigs were blocked by weight and allotted to one of 10 dietary treatments. There were five pigs/pen and 10 pens/treatment. Pigs were housed in the Kansas State University Segregated Early Weaning Facility. Each pen was 4 × 4 ft and contained one self-feeder and one nipple waterers to provide ad libitum access to feed and water.

All pigs were fed the same pelleted SEW and transition diets (Table 1) to 4 d post-weaning. All pigs were fed 1 lb of SEW diet, then they were fed the transition diet for the remainder of the 4 d pretreatment period. At d 4, the pigs were switched to experimental diets, which included a control diet with no added spray-dried blood meal, and diets with 5% regular spray-dried blood meal or irradiated 5% spray-dried blood meal. Irradiated treatments included either gamma ray (cobalt-60 source) or electron beam irradiation at increasing dosage levels (2.5, 5.0 10.0, and 20.0 kGy). All blood meal used in this experiment was from the same lot. Treatment diets were fed in meal form and formulated to contain 1.40% lysine, .90 Ca, and .54 available P (Table 1). In addition, all

[1]Food Animal Health and Management Center.

diets were balanced for Na (.26%) and Cl (.43%). Synthetic amino acids were added as well to exceed the pig requirement and ensure that no amino acid would be limiting in the diets. The ADG, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 4, 11, and 18. Blood meal samples were taken for analysis to determine bacterial concentrations prior to manufacturing of the complete diet.

Data were analyzed as a randomized complete block design with pen as the experimental unit. Pigs were blocked based on postweaning weight, and analysis of variance was performed using the GLM procedure of SAS. Linear, quadratic, and cubic polynomial contrasts were used to determine the effects of increasing dosage levels of irradiation. In addition, contrasts were utilized to test differences between irradiated and non-irradiated treatment diets. Initial pig weight at the start of the experimental period was used as a covariate for statistical analysis.

Results and Discussion

Irradiation of blood meal proved effective in the reduction of aerobic bacteria, *E. coli*, mold, and yeast concentrations (Table 2). Blood meal subjected to gamma ray irradiation had lower concentrations of aerobic bacteria than that irradiated by electron beam at each level of irradiation. In fact, at 5.0, 10.0, and 20.0 kGy, no bacteria were detected with gamma ray treatments, but low levels of bacteria were cultured with electron beam treatment.

From d 0 to 7 of the treatment period (Table 3), as well as overall (d 0 to 14), the inclusion of irradiated spray-dried blood meal tended ($P<.09$) to improve F/G with no effects on ADG ($P=.26$) or ADFI ($P=.86$). However, for the overall experiment, ADG and F/G were increased by approximately 9 and 6%, respectively. In addition, the inclusion of spray-dried blood meal did not improve growth performance over the control diet without spray-dried blood meal.

These results indicate that irradiation is an effective technology to reduce or eliminate bacteria, molds, and yeast in spray-dried blood meal. However, increasing the dosage above 2.5 kGy, regardless of source, did not further enhance growth performance of nursery pigs. Also, both electron beam and gamma ray irradiation resulted in similar performance. Previous research at Kansas State University has consistently shown that ADG and ADFI increase when pigs are fed spray-dried blood meal or animal plasma that has been irradiated. However, in this trial, we found a response in feed efficiency, but not in ADG and ADFI. We believe the numerical responses were similar to the significant responses observed in other trials, but the larger variation (SEM, .038 vs .022) observed in this trial prevented the detection of significant responses. This leads us to believe that pigs can more efficiently utilize irradiated spray-dried blood meal, which indicates that this processing technique either reduces antinutritional factors or alters the protein structure to make it more available for the weanling pig.

Table 1. Compositions of Diets (As-Fed Basis)[a]

	Common Diets		Treatment Diets	
Ingredient, %	SEW	Transition	No Blood Meal Control	Added Blood Meal
Corn	33.37	39.81	45.77	53.63
Soybean meal (46.5%)	12.80	23.30	39.45	26.43
Spray-dried whey	25.00	20.00	10.00	10.00
Spray-dried animal plasma	6.70	2.50	-	-
Select menhaden fish meal	6.00	2.50	-	-
Choice white grease	6.00	5.00	-	-
Lactose	5.00	-	-	-
Spray-dried blood cells	1.65	2.50	-	-
Spray-dried blood meal	-	-	-	5.00
Medication[b]	1.00	1.00	1.00	1.00
Monocalcium phosphate	.75	1.30	1.85	1.86
(21% P)	.45	.73	.82	.79
Limestone	.38	.38	.25	.25
Zinc oxide	.25	.25	.25	.25
Vitamin premix	.20	.30	.38	.30
Salt	.15	.15	.15	.15
Trace mineral premix	-	-	-	.17
Calcium chloride	.15	.15	-	-
L-Lysine HCl	.15	.13	.078	.132
DL-Methionine	-	-	.004	.033
L-Threonine	-	-	-	.006
L-Isoleucine				
Total	100.00	100.00	100.00	100.00
Calculated Analysis				
Lysine, %	1.70	1.60	1.40	1.40
Met:lysine ratio, %	30	30	31	33
Met & Cys:lysine ratio,%	57	57	60	60
Threonine:lysine ratio, %	65	65	67	67
Tryptophan:lysine ratio, %	18	19	21	21
ME, kcal/lb	1,595	1,559	1458	1448
Protein, %	22.4	22.5	23.7	22.7
Calcium, %	.90	.90	.90	.90
Phosphorus, %	.80	.80	.86	.81
Available phosphorus, %	.66	.59	.54	.54

[a]One lb per head of SEW diet was fed, then pigs were fed the transition diet for the remainder of the 4 d pretreatment period. Pigs then were switched to treatment diets from d 4 to 18.
[b]Provided 50 g per ton carbadox.

Table 2. Effects of Source and Dosage Level of Irradiation on Bacterial Concentrations in Spray-Dried Blood Meal[a]

			Blood Meal Irradiated Gamma Ray Dosage, kGy				Blood Meal Irradiated Electron Beam Dosage, kGy			
Item	No Blood Meal Control	Blood Meal Nonirradiatd	2.5	5.0	10.0	20.0	2.5	5.0	10.0	20.0
Blood meal[a]										
Aerobic plate count	N/A	7.9×10^6	1.6×10^4	0	0	0	2.0×10^4	1.0×10^3	3.5×10^4	2.0×10^4
Ecoli coliform count	N/A	2.3×10^3	0	0	0	0	0	0	0	0
Mold and yeast count	N/A	2.40×10^2	0	0	0	0	0	0	0	0
Whole diet[b]										
Total plate count	1.0×10^3	9.2×10^3	6.2×10^2	7.8×10^2	1.2×10^2	4.3×10^2	5.2×10^3	8.2×10^2	9.8×10^2	1.3×10^2
Total coliform count	4.0×10^1	4.1×10^2	2.0×10^1	1.4×10^2	9.4×10^1	0	1.0×10^1	1.5×10^1	3.8×10^1	3.0×10^1

[a]Samples obtained prior to whole diet preparation for analysis. [b]Samples obtained at initiation of experiment for analysis.

Table 3. Effects of Source and Dosage Level of Irradiation on Growth Performance of Nursery Pigs[a]

			Blood Meal Irradiated Gamma Ray Dosage, kGy				Blood Meal Irradiated Electron Beam Dosage, kGy				
Item	No Blood Meal Control	Blood Meal Nonirradiated	2.5	5.0	10.0	20.0	2.5	5.0	10.0	20.0	SEM[bc]
Day 0 to 7											
ADG, lb	.37	.38	.47	.41	.36	.42	.41	.48	.42	.46	.045
ADFI, lb	.65	.69	.74	.69	.65	.73	.69	.74	.66	.73	.044
F/G[d]	1.76	1.82	1.57	1.68	1.81	1.73	1.68	1.54	1.57	1.59	.121
Day 7 to 14											
ADG, lb	1.03	1.02	1.03	1.09	1.15	1.13	1.09	1.03	1.07	1.04	.051
ADFI, lb	1.26	1.34	1.32	1.39	1.40	1.36	1.35	1.34	1.29	1.31	.053
F/G	1.22	1.31	1.28	1.28	1.22	1.20	1.24	1.30	1.21	1.26	.055
Day 0 to 14											
ADG, lb	.70	.70	.75	.75	.76	.77	.75	.76	.75	.75	.038
ADFI, lb	.96	1.01	1.02	1.04	1.02	1.05	1.02	1.04	.97	1.02	.043
F/G[d]	1.37	1.44	1.36	1.39	1.34	1.36	1.36	1.37	1.29	1.36	.052

[a]A total of 300 pigs (five pigs per pen and 6 pens per treatment) with an average initial BW of 23.7 lbs. [b]No effect of control diet vs added blood meal diets (P>.10). [c]No effect of gamma ray verses electron beam irradiation (P>.10). [d]Nonirradiated vs irradiated blood meal (P<.10).

EFFECTS OF IRRADIATION PROCESSING OF SPECIALITY PROTEIN PRODUCTS ON NURSERY PIG PERFORMANCE

J. M. DeRouchey, M. D. Tokach, J. L. Nelssen, R. D. Goodband, S. S. Dritz[1], J. C. Woodworth, M. J. Webster, B. W. James, and D. E. Real

Summary

Three hundred weanling pigs (initially 13.4 lb and 20 ± 2 d of age) were used in a 14-d growth assay to determine the effects of irradiation processing of specialty protein products on nursery pig performance. Overall, irradiated of AP 920 and Peptide-Plus™ resulted in increased ADG compared to nonirradiated products. Irradiation of Peptide-Plus® improved feed efficiency compared to its nonirradiated form. Also, ADG was greater for pigs fed diets containing ProtiOne™ and DPS 30 and tended to increase with AP 920 compared to those fed the control diet. In addition, feed efficiency was improved for pigs fed diets containing ProtiOne™, DPS 30, Peptide-Plus™, and spray-dried egg compared to those fed the control diet. Therefore, adding specialty protein products to diets in most cases improved growth performance, and irradiation processing improved growth performance with certain specialty protein products.

(Key Words: Nursery Pigs, Irradiation, Speciality Protein.)

Introduction

Currently, a variety of dried blood and egg by-products are commercially available for use in diets for early-weaned pigs. Recent research conducted at Kansas State University has shown improvements in growth performance of nursery pigs fed diets that had irradiated spray-dried animal plasma or spray-dried blood meal compared to nonirradiated forms. Although the mechanism for improved growth performance is unclear, we believe that it may be due to an increase in digestibility. This may involve a breakdown of antinutritional factors associated with the ingredients or structural changes in the protein complex that make the protein more available to the young pig. In addition, a reduction in the bacterial concentration within the product occurs, which may increase pig performance as well. Therefore, our objective was to compare the effects of irradiation of several different commercially available specialty protein products on nursery pig performance.

Procedures

A total of 330 pigs (initially 13.4 lb and 20 ± 2 d of age) were used in a 14-d growth assay. Pigs were blocked by weight and allotted to one of 11 dietary treatments. There were five pigs/pen and six pens/treatment. Pigs were housed in the Kansas State University Segregated Early Weaning Facility. Each pen was 4 × 4 ft and contained one self-feeder and one nipple water to provide ad libitum access to feed and water.

All diets were fed in pelleted form (Table 1). The diets were formulated to contain 1.50% lysine, .90% Ca, .80% P, .46% Na, and .57% Cl. In addition, 2.50% fish meal and .15% crystalline lysine were added to all diets, with other crystalline amino acids (methionine, threonine, isoleucine, and tryptophan) included (if necessary) to maintain similar ratios of amino acids related to lysine. Experimental treatments included a

[1]Food Animal Health and Management Center.

control diet or the control diet with either 5% spray-dried animal plasma (American Protein Corporation, AP 920); animal plasma, dried egg product, animal serum, serum albumin, and serum globulin combination (DuCoa L.P., ProtiOne™); dried porcine digest (Nutra-Flo Protein Products, DPS 30); liquefied and spray-dried beef muscle (Esteem Products Inc., Peptide Plus™); and spray-dried whole egg (California Spray Dry Company). All specialty protein products were either fed irradiated or as-is and originated from the same lot for each source. Irradiated protein sources were processed with gamma ray (cobalt-60 source) irradiation at an average dose of 8.5 kGy. Because all added specialty protein products were included at 5% of the total diet, soybean meal was allowed to vary depending on the nutrient profile of the specialty protein product. All speciality protein products were included in the diet at a fixed amount and not on a nutrient profile basis, so direct comparisons between specialty protein products were not made. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 7 and 14. Samples of the specialty protein products were obtained prior to feed manufacturing of the complete feed for bacterial analysis.

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

Results and Discussion

For d 0 to 7 (Table 2), irradiation of AP 920 ($P<.05$) and Peptide-Plus® ($P<.10$) resulted in greater ADG than their nonirradiated forms. Irradiation of Peptide-Plus® improved feed efficiency numerically ($P<.10$) compared to nonirradiated Peptide-Plus®. In addition, nonirradiated AP 920, ProtiOne™, and DPS 30 increased ADG ($P<.05$), and nonirradiated spray-dried egg tended to improve ($P<.10$) ADG compared to the control diet. Also, ADFI was increased ($P<.05$) with ProtiOne™ and tended to increase ($P<.10$) with AP 920 and Peptide-Plus™ compared to the control diet. Furthermore, feed efficiency was improved ($P<.05$) for pigs fed diet diets containing nonirradiated ProtiOne™, DPS 30, and spray-dried egg and tended to improve ($P<.10$) with AP 920 and Peptide-Plus™ compared to pigs fed the control diet. Overall, irradiated AP 920 and Peptide-Plus™ resulted in increased ($P<.05$) ADG more than their nonirradiated forms. Irradiation of Peptide-Plus™ improved ($P<.05$) feed efficiency compared to its nonirradiated form. Also, ADG was greater ($P<.05$) for pigs fed diets containing ProtiOne™ and DPS 30 and tended ($P<.10$) to increase with AP 920 compared to those fed the control diet. In addition, feed efficiency was improved ($P<.05$) for pigs fed diets containing ProtiOne™, DPS 30, Peptide-Plus™, and spray-dried egg compared to those fed the control diet.

Bacterial concentrations of the specialty protein products varied widely, with AP 920 having the highest concentration and Peptide-Plus™ the lowest (Table 3). Irradiation processing did prove to be an effective technique to reduce the bacterial level in each of the products. However, no consistent improvements in growth performance were observed in response to the reduction of bacteria within each source. This is evidenced by AP 920 and Peptide-Plus™, which had the highest and the lowest bacterial concentrations, yet were the only two products that elicited responses to irradiation processing. This suggests that improvements in growth performance are not based on a decrease in bacteria, but rather an increase in digestibility or a decrease in antinutritional factors associated with the product. Therefore, adding specialty protein products to diets improved growth performance in most cases, whereas irradiation processing improved growth performance on a more limited basis in these commercial products. The lack of response to irradiation in some ingredients possibly can be explained by different manufacturing techniques and/or nutrient profiles for each of these products. In addition, alterations of inclusion levels for each specialty protein product may influence the response to irradiation treatment.

Table 1. Compositions of Experimental Diets (As-Fed Basis)

Ingredient, %	Control	AP 920	ProtiOne™	DSP 30	Peptide-Plus™	Spray-Dried Egg
Corn	34.87	42.36	42.24	33.68	39.76	35.15
Soybean meal, 46.5 %	32.81	20.84	20.75	29.52	23.78	27.66
Spray-dried whey	20.00	20.00	20.00	20.00	20.00	20.00
AP 920	-	5.00	-	-	-	-
ProtiOne™	-	-	5.00	-	-	-
DPS 30	-	-	-	5.00	-	-
Peptide-Plus™	-	-	-	-	5.00	-
Spray-dried egg	-	-	-	-	-	5.00
Soybean oil	5.00	5.00	5.00	5.00	5.00	5.00
Fish meal	2.50	2.50	2.50	2.50	2.50	2.50
Monocalcium P, 21 %	1.21	1.10	1.24	1.22	.47	1.22
Limestone	.75	.89	.77	.62	.86	.77
Antibiotic[a]	1.00	1.00	1.00	1.00	1.00	1.00
Salt	.37	.25	.31	.19	.07	.38
Zinc oxide	.39	.39	.39	.39	.39	.39
Vitamin premix	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15
Sodium bicarbonate	.38	-	-	-	-	.28
Calcium chloride	-	-	.08	.18	.38	-
L-Lysine HCl	.15	.15	.15	.15	.15	.15
DL-Methionine	.13	.10	.15	.10	.14	.07
L-Threonine	.04	.01	.02	.04	.08	.03
L-Tryptophan	-	.01	-	.01	.02	-
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis						
Lysine, %	1.50	1.50	1.50	1.50	1.50	1.50
Met:lysine ratio,	32	28	28	31	35	31
Met & Cys:lysine ratio,%	57	57	57	57	57	57
Threonine:lysine ratio, %	64	64	64	64	64	64
Isoleucine:lysine ratio, %	66	61	61	65	64	69
Tryptophan:lysine ratio, %	19	19	19	19	19	19
Sodium, %	.46	.46	.46	.46	.46	.46
Chloride, %	.58	.58	.58	.58	.58	.58
ME, kcal/lb	1564	1585	1585	1578	1573	1625
dEB	353	297	297	352	308	332

[a]Provided 50 g per ton carbadox.

Table 2. Growth Performance of Nursery Pigs Fed Various Specialty Protein Products (Regular or Irradiated)[a]

		AP 920		ProtiOne™		DPS 30		Peptide-Plus™		Spray-Dried Egg		
Item	Control	Regular	Irradiated	Regular	Irradiated	Regular	Irradiated	Regular	Irradiated	Regular	Irradiated	SEM
D 0 to 7												
ADG, lb	.43	.52[b]	.60[d]	.59[b]	.59	.53[b]	.52	.43	.50[e]	.49[c]	.46	.03
ADFI, lb	.43	.49[c]	.55	.50[b]	.50	.43	.45	.38[c]	.40	.42	.38	.02
F/G	1.01	.94[c]	.92	.85[b]	.85	.81[b]	.86	.88[c]	.80[e]	.86[b]	.83	.04
D 7 to 14												
ADG, lb	.58	.59	.62	.68[b]	.63	.71[b]	.69	.59	.64	.61	.62	.03
ADFI, lb	.71	.72	.76	.73	.70	.75	.75	.66	.67	.70	.68	.03
F/G	1.22	1.22	1.23	1.07[b]	1.11	1.06[b]	1.09	1.11	1.05	1.15	1.10	.05
D 0 to 14												
ADG, lb	.50	.56[c]	.61[e]	.63[b]	.61	.62[b]	.60	.51	.57[e]	.55	.54	.02
ADFI, lb	.57	.61	.65	.62	.62	.59	.60	.52	.53	.56	.53	.02
F/G	1.14	1.09	1.07	.98[b]	1.02	.95[b]	1.00	1.02[b]	.93[d]	1.02[b]	.98	.03

[a]A total of 330 pigs (five pigs per pen and six pens per treatment) with an initial BW of 13.4 lb. Specialty protein products include: spray-dried animal plasma (American Protein Corporation, AP 920); animal plasma, dried egg product, animal serum, serum albumin, and serum globulin combination (DuCoa L.P., ProtiOne™); dried porcine digest (Nutra-Flo Protein Products, DPS 30); liquefied and spray-dried beef muscle (Esteem Products Inc., Peptide Plus™); and spray-dried whole egg (California Spray Dry Company).

[bc]Control diet versus nonirradiated (regular) specialty protein source, P<.05 and P<.10, respectively.

[de]Irradiated versus nonirradiated (regular) specialty protein source, P<.05 and P<.10, respectively.

Table 3. Bacterial Concentrations of Various Specialty Protein Products (Regular or Irradiated)

		AP 920		ProtiOne™		DPS 30		Peptide-Plus™		Spray-Dried Egg	
Item	Control	Regular	Irradiated	Regular	Irradiated	Regular	Irradiated	Regular	Irradiated	Regular	Irradiated
Total Plate Count[a]	N/A	8.7×10^4	7.0×10^1	6.9×10^3	3.0×10^1	1.0×10^3	3.0×10^1	2.6×10^2	2.0×10^1	4.7×10^3	1.0×10^1

[a]Samples obtained prior to manufacturing of complete diet.

COMPARISONS OF LYSINE BIOAVAILABILITY IN SPRAY-DRIED BLOOD MEAL, BLOOD CELLS, AND CRYSTALLINE LYSINE IN NURSERY PIGS

J. M. DeRouchey, J. L. Nelssen, M. D. Tokach, R. D. Goodband, S. S. Dritz[1], J. C. Woodworth, and B. W. James

Summary

Three hundred thirty-three nursery pigs (initially 23.7 lb) were used in a 21-d growth assay to determine the lysine bioavailability of spray-dried blood meal, blood cells, and crystalline lysine on growth performance. Regardless of lysine source, ADG improved linearly as dietary lysine increased. However, pigs fed diets containing blood cells gained faster then those fed diets with spray-dried blood meal. Pigs fed diets containing crystalline lysine and blood cells had greater ADFI then pigs fed spray-dried blood meal. Feed efficiency improved by 11.6, 13.6, and 12.7% with increasing amounts of L-lysine HCl, spray-dried blood meal, and blood cells, respectively. If L-lysine has a lysine bioavailability of 100%, the lysine bioavailabilities of spray-dried blood meal and blood cells, as determined by a slope-ratio, were 103 and 102%, respectively.

(Key Words: Nursery Pigs, Lysine, Spray-Dried Blood Meal, Blood Cells.)

Introduction

The use of specialty protein products or crystalline amino acids to replace a portion of soybean meal has become common practice in nursery diets. In addition, research has shown that amino acid digestibility is greater in some of these alternative sources compared to soybean meal. Furthermore, differences between sources can exist. In recent years, the use of spray-dried blood meal and blood cells in nursery diets has gained popularity with swine nutritionists as a means to reduce the amount of soybean meal. Therefore, our objective was to determine differences in lysine bioavailability between spray-dried blood meal, blood cells, and crystalline lysine.

Procedures

A total of 330 pigs (BW of 23.7 lb) was used in a 21-d growth assay. Pigs were blocked by weight and allotted to one of 11 dietary treatments. There were five pigs/pen and six pens/treatment. Pigs were housed in the Kansas State University Segregated Early Weaning Facility. Each pen was 4 × 4 ft and contained one self-feeder and one nipple water to provide ad libitum access to feed and water.

Diets for the experiment included both a negative (.95% lysine) and positive (1.40% lysine) control with no added blood products or crystalline lysine (Table 1). Additional treatment diets were formulated to increase the lysine level in the negative control diet by .15% increments (1.10, 1.25, and 1.40%) through the addition of L-lysine HCl, spray-dried blood meal, or blood cells. Corn and soybean meal were held constant in all diets except the positive control, so changes in the levels of the above ingredients were determined by the lysine level. In addition, all diets were formulated to equal levels of energy, sodium, and chloride. Increased amounts of crystalline amino acids (methionine, threonine, isoleucine, tryptophan, and valine) were included in the diet as lysine concentration rose, especially for the diets containing no blood products to maintain a

[1]Food Animal Health and Management Center.

minimum ratio as suggested by the NRC (1998). Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 7, 14, and 21 of the treatment period.

Data were analyzed as a randomized complete block design with pen as the experimental unit. Linear and quadratic polynomial contrasts were used to determine the effects of increasing lysine levels from crystalline lysine, spray-dried blood meal, and blood cells in the diet.

Results and Discussion

Overall, pigs fed the positive control diet had improved ADG and feed efficiency compared to those fed the negative control diet (P<.001; Table 2). Regardless of lysine source, ADG improved linearly (P<.05) as dietary lysine increased. Pigs fed diets containing blood cells gained faster (P<.02) then those fed spray-dried blood meal. Average daily feed intake tended to decrease linearly (P<.08) with increasing spray-dried blood meal. In addition, a quadratic decrease (P<.001) in ADFI occurred with increasing amounts of crystalline lysine in the diet. However, pigs consumed more of diets containing crystalline lysine (P<.001) and blood cells (P<.01) compared to diets with spray-dried blood meal. This indicates that spray-dried blood meal may be less palatable to pigs when fed at high levels (>5%). The reduction in intake conflicts with other research indicating an increase in feed consumption with elevated levels of spray-dried blood meal compared to blood cells. However, that research was conducted with smaller and younger pigs, which may indicate a possible decrease in palatability for spray-dried blood meal as pigs get older.

As the lysine level increased in the diet, pigs had a linear improvement in F/G (P<.007), regardless of lysine source. Feed efficiency increased by 11.6, 13.6, and 12.7% when they consumed diets with increasing amount of synthetic lysine, spray-dried blood meal, and blood cells, respectively.

To determine the lysine bioavailability of spray-dried blood meal and blood cells relative to synthetic lysine, a slope-ratio of the efficiency of gain response was utilized. If L-lysine has a lysine bioavailability of 100%, the lysine bioavailabilities of spray-dried blood meal and blood cells were 103 and 102%, respectively. These data are in agreement with previous research showing that blood meal (ring-dried) had a greater lysine bioavailability than crystalline lysine. This is supported by the fact that pigs in our study were more efficient when fed diets containing spray-dried blood meal (P<.03) and tended to be more efficient when fed diets containing blood cells (P<.14) compared to diets containing crystalline lysine.

These findings indicate that the use of blood products in diets is beneficial for increasing efficiency of gain compared to the use of crystalline lysine. Furthermore, the lysine bioavailability of spray-dried blood meal and blood cells is equal to or slightly greater than that of crystalline lysine.

Table 1. Diet Compositions (As-Fed Basis)

	Negative Control	L-Lysine HCl			Blood Meal			Blood Cells			Positive Control
Item	.95[a]	1.10%	1.25%	1.40%	1.10%	1.25%	1.40%	1.10%	1.25%	1.40%	1.40%
Corn	58.070	58.070	58.070	58.070	58.070	58.070	58.070	58.070	58.070	58.070	49.612
Soybean meal, 46.5%	26.458	26.458	26.458	26.458	26.458	26.458	26.458	26.458	26.458	26.458	42.086
Soy oil	2.987	3.090	3.269	3.577	3.433	3.901	4.409	3.425	3.884	4.414	3.932
Corn starch	8.000	7.514	6.839	5.893	5.571	3.076	.498	5.758	3.445	.982	-
Spray-dried blood meal	-	-	-	-	2.013	4.027	6.040	-	-	-	-
Blood cells	-	-	-	-	-	-	-	1.763	3.525	5.288	-
Monocalcium P, 21%	1.683	1.683	1.683	1.683	1.656	1.630	1.604	1.683	1.683	1.683	1.581
Limestone	.891	.975	.975	.975	.854	.817	.781	.921	.952	.973	.810
Salt	.428	.408	.345	.283	.406	.383	.361	.402	.376	.350	.425
Antibiotic[b]	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Vitamin premix	.250	.250	.250	.250	.250	.250	.250	.250	.250	.250	.250
Trace mineral premix	.150	.150	.150	.150	.150	.150	.150	.150	.150	.150	.150
Calcium chloride	.075	-	-	-	.099	.123	.147	.047	.019	-	.069
Sodium bicarbonate	-	.029	.121	.212	-	-	-	-	-	-	-
L-Lysine HCl	-	.190	.381	.571	-	-	-	-	-	-	-
DL-Methionine	.009	.079	.170	.261	.037	.087	.137	.053	.119	.185	.069
L-Threonine	-	.080	.182	.284	.003	.028	.053	.020	.061	.103	.016
L-Isoleucine	-	-	.016	.106	-	-	.044	-	-	.080	-
L-Tryptophan	-	.025	.057	.089	-	-	-	-	.007	.015	-
L-Valine	-	-	.035	.139	-	-	-	-	-	-	-
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis											
Lysine, %	.95	1.10	1.25	1.40	1.10	1.25	1.40	1.10	1.25	1.40	1.40
Met:lysine ratio, %	30	32	36	38	30	32	34	31	34	36	31
Met & cys:lysine ratio, %	62	60	60	60	60	60	60	60	60	60	60
Threonine:lysine ratio, %	69	67	67	67	67	67	67	67	67	67	67
Isoleucine:lysine ratio, %	77	67	60	60	69	62	60	68	60	60	75
Choride, %	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19
Soduim, %	.32	.32	.32	.32	.32	.32	.32	.32	.32	.32	.32
ME, kcal/lb	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565

[a]Calculated lysine level.

[b]Provided 50 g/ton carbadox.

Table 2. Effects of Source and Level of Dietary Lysine on Growth Performance of Phase III Nursery Pigs[a]

	Negative Control	L-Lysine Hcl			Blood Meal			Blood Cells			Positive Control
Item	.95[b]	1.10%	1.25%	1.40%	1.10%	1.25%	1.40%	1.10%	1.25%	1.40%	1.40%
Day 0 to 7											
ADG, lb	.97	1.14	1.07	1.25	1.07	1.15	1.18	1.08	1.23	1.25	1.27
ADFI, lb	1.46	1.54	1.41	1.60	1.50	1.41	1.42	1.47	1.53	1.49	1.47
F/G	1.51	1.35	1.32	1.28	1.40	1.23	1.20	1.36	1.24	1.19	1.16
Day 7 to 14											
ADG, lb	1.18	1.32	1.37	1.41	1.31	1.36	1.40	1.33	1.45	1.45	1.52
ADFI, lb	1.98	2.06	1.79	1.85	1.93	1.89	1.77	1.90	1.97	1.93	1.99
F/G	1.68	1.56	1.31	1.31	1.47	1.46	1.26	1.43	1.36	1.33	1.31
Day 14 to 21											
ADG, lb	1.33	1.50	1.52	1.65	1.52	1.53	1.52	1.45	1.55	1.63	1.55
ADFI, lb	2.51	2.49	2.44	2.51	2.40	2.29	2.21	2.47	2.43	2.39	2.41
F/G	1.89	1.66	1.61	1.52	1.58	1.50	1.45	1.70	1.57	1.47	1.55
Day 0 to 21											
ADG, lb	1.16	1.32	1.32	1.44	1.30	1.35	1.36	1.29	1.41	1.44	1.45
ADFI, lb	1.98	2.03	1.88	1.99	1.95	1.86	1.80	1.95	1.97	1.94	1.96
F/G	1.71	1.54	1.42	1.38	1.50	1.38	1.32	1.51	1.40	1.34	1.35
Final wt, lb	47.77	50.65	49.20	53.28	50.21	51.30	51.53	49.89	52.78	53.33	53.44

[a]A total of 330 pigs (five pigs per pen and 6 pens per treatment) with an average initial BW of 23.7 lb.

[b]Calculated lysine level in the diet.

Table 3. Probability of Source and Level of Dietary Lysine on Growth Performance of Phase III Nursery Pigs[a]

Item	Negative vs Positive Control	Positive vs Other 1.40% Lysine Diets	L-Lysine vs Blood Meal	L-Lysine vs Blood Cells	Blood Meal vs Blood Cells	L-Lysine		Blood Meal		Blood Cells		SE
						Lin	Quad	Lin	Quad	Lin	Quad	
Day 0 to 7												
ADG, lb	.001	.26	.57	.23	.08	.07	.03	.004	.29	.03	.27	.03
ADFI, lb	.84	.59	.04	.54	.15	.40	.01	.23	.36	.85	.43	.04
F/G	.001	.10	.13	.06	.73	.05	.94	.006	.15	.02	.49	.04
Day 7 to 14												
ADG, lb	.001	.04	.75	.24	.14	.06	.84	.23	.96	.07	.25	.04
ADFI, lb	.93	.10	.53	.60	.25	.06	.09	.31	.77	.60	.35	.07
F/G	.001	.91	.84	.75	.91	.02	.13	.13	.87	.31	.67	.06
Day 14 to 21												
ADG, lb	.001	.42	.30	.76	.46	.07	.40	.82	.58	.003	.69	.04
ADFI, lb	.22	.52	.001	.24	.001	.82	.51	.03	.87	.31	.96	.06
F/G	.001	.21	.02	.51	.09	.02	.68	.09	.58	.001	.43	.04
Day 0 to 21												
ADG, lb	.001	.17	.20	.24	.02	.004	.06	.05	.51	.001	.14	.02
ADFI, lb	.63	.24	.001	.65	.01	.20	.001	.08	.89	.86	.44	.04
F/G	.001	.96	.03	.14	.49	.001	.26	.007	.51	.001	.32	.03
Final wt, lb	.001	.65	.95	.08	.07	.08	.04	.07	.44	.08	.04	.65

[a]A total of 330 pigs (five pigs per pen and 6 pens per treatment) with an average initial BW of 23.7 lb.

[b]Calculated lysine level in the diet.

EFFECTS OF INCREASING LEVELS OF SPRAY-DRIED BLOOD MEAL AND BLOOD CELLS ON NURSERY PIG PERFORMANCE[1]

J. M. DeRouchey, J. L. Nelssen, M. D. Tokach, R. D. Goodband, S. S. Dritz[2], and B. W. James

Summary

Three hundred fifty weanling pigs (initially 14.6 lbs and 17 ± 2 d of age) were used in a 19-d growth assay to determine the effects of increasing levels (2.5, 5.0, and 7.5%) of spray-dried blood meal or blood cells in the diet on growth performance. Overall, the dietary inclusion of both blood products improved ADG and feed efficiency. However, spray-dried blood meal improved ADG, ADFI, and F/G from d 0 to 7 more compared to blood cells. The greatest differences during this period occurred at the 5 and 7.5% inclusion levels. No differences in growth performance were detected from d 7 to 14. Therefore, when high levels (>5%) of blood products are used in nursery diets immediately after weaning, spray-dried blood meal provides some advantage over blood cells, but the advantage may be lost in the overall period.

(Key Words: Nursery Pig, Blood Meal, Blood Cells.)

Introduction

The benefits of increased growth performance of newly weaned pigs fed spray-dried blood meal and blood cells are well known. However, the response to increasing levels of these animal products has not yet been well established. Typically, high levels of spray-dried blood meal and blood cells are not included in nursery pig diets. This is because amino acids such as methionine and isoleucine may become limiting if crystalline amino acids are not used. Spray-dried blood meal contains the plasma fraction of the blood, but blood cells do not. Plasma has been proven to help increase growth performance; thus, including blood meal at increasing levels in the diet could be beneficial. Therefore, our objective was to determine the effects of increasing levels (2.5, 5.0, and 7.5%) of spray-dried blood meal and blood cells on nursery pig performance.

Procedures

A total of 350 pigs (BW of 14.6 lbs and 17 ± 2 d of age) was used in a 19-d growth assay. Pigs were blocked by weight and allotted to one of seven dietary treatments with five pigs/pen and 10 pens/treatment. Pigs were housed in the Kansas State University Segregated Early Weaning Facility. Each pen was 4 × 4 ft and contained one self-feeder and one nipple waters to provide ad libitum access to feed and water. The temperature was 90°F for the first 5 d and was lowered approximately 3°F each week thereafter.

All pigs were fed the same pelleted SEW diet (Table 1) to 5 d after weaning. Then the pigs were fed experimental diets, which included a control with no added blood products and diets containing either spray-dried blood meal or blood cells at 2.5, 5.0, and 7.5% of total ingredients. The blood products replaced soybean meal in the diet on a lysine basis. Crystalline amino acids

[1]Appreciation is expressed to Jerry Ball of California Spray Dry Company, Stockton, CA, for partial financial support.

[2]Food Animal Health and Management Center.

(methionine, threonine, isoleucine, and tryptophan) were included as the level of the blood products was increased, especially for the diets containing blood cells to maintain similar ratios of amino acids related to lysine that met or exceeded NRC, 1998 ratios . Treatment diets were fed in meal form; formulated to contain 1.40% lysine, .90 Ca, and .54 available P; and balanced for Na and Cl concentrations (Table 2). Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 5, 12, and 19 after weaning.

Table 1. Composition of Common Diet[a]

Ingredient, %	SEW
Corn	33.37
Spray-dried whey	25.00
Soybean meal (46.5%)	12.80
Spray-dried animal plasma	6.70
Select menhaden fish meal	6.00
Choice white grease	6.00
Lactose	5.00
Spray-dried blood cells	1.65
Medication[b]	1.00
Monocalcium P (21% P)	.75
Limestone	.45
Zinc oxide	.38
Vitamin premix	.25
Salt	.20
Trace mineral premix	.15
L-Lysine HCl	.15
DL-Methionine	.15
Total	100.00
Calculated Analysis	
Lysine, %	1.70
Met:lysine ratio, %	30
Met & Cys:lysine ratio,%	57
Threonine:lysine ratio, %	65
Tryptophan:lysine ratio, %	18
ME, kcal/lb	1,595
Protein, %	22.4
Calcium, %	.90
Phosphorus, %	.80
Available phosphorus, %	.66
Lysine:calorie ratio, g/Mcal ME	4.83

[a]Pigs consumed SEW diet for 5 d, then were fed experimental diets.
[b]Provided 50 g per ton carbadox.

Data were analyzed as a randomized complete block design with pen as the experimental unit. Pigs were blocked based on weaning weight, and analysis of variance was performed using the GLM procedure of SAS. Linear and quadratic polynomial contrasts were used to determine the effects of increasing spray-dried blood meal and blood cells in the diet. Initial pig weight at the start of the experimental period was used as a covariate for statistical analysis.

Results and Discussion

From d 0 to 7, the inclusion of both blood products improved feed efficiency (P<.001) compared to the control diet (Table 3). In addition, pigs fed diets containing spray-dried blood meal had improved ADG (P<.001), ADFI (P<.04), and F/G (P<.001) compared to pigs fed blood cells. Furthermore, ADG (P<.07) and feed efficiency (P<.001) improved linearly with increasing levels of spray-dried blood meal, whereas ADG (P<.06) and ADFI (P<.03) decreased linearly as the level of blood cells was elevated above 2.5% of the diet.

From d 7 to 14, ADG (P<.001) and F/G (P<.002) were increased for pigs fed diets containing blood products versus the control. Also, feed efficiency increased (P<.03) for pigs consuming increasing levels of blood cells in the diet.

Overall, pigs gained faster (P<.005) and were more efficient (P<.001) when blood products were included into the diet. Also, ADFI was numerically higher (P<.09) for pigs consuming diets containing spray-dried blood meal compared to diets with blood cells, but no differences occurred in ADG or F/G. As spray-dried blood meal increased from 2.5% to 7.5% in the diet, F/G (P<.04) improved, and ADG showed a trend for increasing (P<.10). Increasing blood cells had no effect (P>.10) on ADG, ADFI, or feed efficiency, although efficiency of gain was improved by 9% as the blood cell level was increased in the diet.

In conclusion, the results from this experiment indicate that the inclusion of increas-

ing levels of spray-dried blood meal compared to blood cells in nursery diets was beneficial for the first week of the experiment. This may be attributed to the plasma that is present in this product. The decrease in performance with increased blood cells during the first week may indicate a possible palatability concern. In addition, regardless of blood source, improvements in ADG and F/G were realized compared to the diets containing no blood products. Also, efficiency of gain was increased with spray-dried blood meal (11%) and blood cells (9%) as the level of each was increased in the diet.

Table 2. Compositions of Experimental Diets (As-Fed Basis)[a]

	No Blood	Blood Meal			Blood Cells		
Ingredients, %	Control	2.5 %	5.0 %	7.5 %	2.5 %	5.0 %	7.5 %
Corn	45.68	49.65	53.62	57.45	50.49	55.22	59.87
Soybean meal, (46.5%)	39.45	32.94	26.43	19.93	31.99	24.53	17.09
Spray-dried whey	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Spray-dried blood meal	-	2.50	5.00	7.50	-	-	-
Blood cells	-	-	-	-	2.50	5.00	7.50
Monocalcium P, (21% P)	1.84	1.86	1.86	1.87	1.89	1.94	1.98
Limestone	.82	.80	.79	.78	.90	.98	1.06
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Salt	.36	.33	.30	.28	.32	.29	.25
Zinc oxide	.25	.25	.25	.25	.25	.25	.25
Vitamin premix	.25	.25	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15	.15	.15
Calcium chloride	.11	.14	.18	.21	.08	.04	-
DL-Methionine	.08	.11	.13	.16	.13	.18	.24
L-Threonine	.01	.02	.03	.05	.04	.08	.13
L-Isoleucine	-	-	.01	.11	-	.07	.20
L-Tryptophan	-	-	-	.01	.01	.02	.03
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis							
Lysine, %	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Met:lysine ratio, %	31	32	33	34	33	36	38
Met & Cys:lysine ratio, %	60	60	60	60	60	60	60
Threonine:lysine ratio, %	67	67	67	67	67	67	67
Isoleucine:lysine ratio, %	74	67	60	60	65	60	60
Tryptophan:lysine ratio, %	22	21	21	21	21	21	21
Chloride, %	.43	.43	.43	.43	.43	.43	.43
Sodium, %	.26	.26	.26	.26	.26	.26	.26
Potassium, %	1.19	1.07	.95	.83	1.06	.94	.81
Dietary electrolyte balance, mEq/kg	296	264	233	201	262	230	197
ME, kcal/lb	1458	1453	1449	1442	1452	1445	1438

[a]Experimental diets were fed from d 5 to 19 after weaning.

[b]Provided 50 g/ton carbodox.

Table 3. Effects of Increasing Levels of Spray-Dried Blood Meal and Blood Cells on Growth Performance of Weanling Pigs[ab]

									Probability					
	No Blood	Blood Meal			Blood Cells				Control vs	Meal vs	Blood Meal		Blood Cells	
Item	Control	2.5%	5.0%	7.5%	2.5%	5.0%	7.5%	SE	Others	Cells	Lin	Quad	Lin	Quad
Initial wt, lb	14.39	14.74	14.69	14.64	14.75	14.34	14.57	.17	.15[c]	.40	.55	.73	.62	.12
Day 0 to 7														
ADG, lb	.32	.35	.39	.40	.36	.31	.29	.02	.21	.001	.07	.73	.06	.74
ADFI, lb	.58	.58	.58	.57	.59	.58	.49	.03	.52	.04	.88	.85	.03	.46
F/G	1.81	1.65	1.48	1.43	1.64	1.87	1.69	.08	.001	.001	.01	.89	.16	.95
Day 7 to 14														
ADG, lb	.61	.70	.71	.73	.73	.73	.80	.04	.001	.21	.38	.94	.17	.32
ADFI, lb	.92	.98	.99	.97	.96	.91	.95	.04	.38	.25	.85	.88	.84	.29
F/G	1.51	1.40	1.39	1.33	1.32	1.25	1.19	.05	.002	.32	.25	.84	.03	.79
Day 0 to 14														
ADG, lb	.46	.52	.55	.57	.54	.52	.55	.02	.005	.60	.10	.91	.99	.40
ADFI, lb	.75	.78	.78	.77	.78	.71	.72	.03	.81	.09	.96	.85	.22	.32
F/G	1.63	1.50	1.42	1.35	1.44	1.37	1.31	.09	.001	.24	.04	.99	.16	.68
Final wt, lb	20.76	21.99	22.42	22.60	22.26	21.81	22.17	.46	.001	.94	.20	.88	.82	.29

[a]A total of 350 pigs (five pigs per pen and 10 pens per treatment) with an average initial BW of 14.6 lbs. at the beginning of the treatment period. All pigs were fed a common SEW diet for first 5 days. Thus, d 0 of the experiment is actually 5 days after weaning.

[b]Growth performance for the first 5 d after weaning was: ADG, .27 lb; ADFI, .24 lb; and F/G, .89.

[c]Initial pig weight was used as a covariate in the statistical analysis of growth performance.

EFFECTS OF FREE FATTY ACID CONCENTRATIONS IN CHOICE WHITE GREASE ON GROWTH PERFORMANCE AND NUTRIENT DIGESTIBILITY IN WEANLING PIGS

J. M. DeRouchey, J. D. Hancock, R. H. Hines, H. Cao, C. A. Maloney, D. W. Dean, D. J. Lee, and J. S. Park

Summary

As much as 53% free fatty acids in choice white grease did not adversely affect piglet performance. Thus, concentration of free fatty acids, if they are not otherwise damaged or rancid, is not an acceptable measure of fat quality.

(Key Words: Weanling Pigs, Fat Quality, Free Fatty Acids)

Introduction

Using fat to improve growth performance in nursery pigs is a common practice. However, research about fat utilization in young pigs has been focused on the effects of unsaturated:saturated fatty acid ratios, chain length of the fatty acids, and age of pigs when fat is added to the diet. Thus, few data are available about the effects of "fat quality" (e.g., free fatty acids) and growth performance in pigs. Our objective was to determine the effects of free fatty acids in choice white grease on growth performance and nutrient digestibility in weanling pigs.

Procedures

One hundred twenty five weanling pigs (lines C 22 × 326, PIC, Frankiln KY) with an average initial BW of 13.7 lb were used in a 33-d growth assay. The pigs were weaned and allotted by BW, sex, and ancestry to five treatments. Initial BW was used as the blocking criterion. The diets (Table 1) were formulated to 1.70% lysine for d 0 to 5, 1.55% lysine for d 5 to 19, and 1.40% lysine for d 19 to 33. They also met or exceeded all nutrient requirements as defined by NRC (1998). Treatments were a corn-soybean meal-based diet with no added fat; 6% choice white grease; and 6% choice white grease that had been heated at 95°F and treated with 872, 1,175, and 2,248 lipase units/g of fat. The choice white grease allotted for lipase addition was divided in three barrels (55 gal capacity) with 65 lb per barrel, and heaters were attached to maintain a constant temperature. Fat treated with lipase was mixed with water, the lipase was added, and the mixture was agitated for 12 h. The mixture was allowed to stand for 24 h (for separation of the fat and water), and the water was pumped from the bottom of the barrel.

Pigs for the experiment were housed in an environmentally controlled building with a self-feeder and nipple water in each pen to allow ad libitum consumption of feed and water. Pigs and feeders were weighed on d 5, 19, and 33 to allow calculation of ADG, ADFI, and gain/feed.

Pen was the experimental unit. The GLM procedures of SAS were used for all statistical analyses. Polynomial regression was used to determine the shape of the response to increasing free fatty acids in the choice white grease.

Results and Discussion

Chemical analyses of the fat treatments indicated that percentage of free fatty acids increased (from 2 to 53%) as lipase addition to the fat was increased from none to 2,248 lipase units/g of fat (Table 2). Peroxide and p-anisidine values and percentage insoluble impurities and unsaponifiable matter were unchanged as lipase treatment was increased. Also, fatty acid composition, iodine value, and U/S ratio remained virtually unchanged

as indicated by enzyme hydrolysis of the choice white grease. However, moisture increased as the extent of lipase treatment was increased, indicating that less water separation from the choice white grease was possible as free fatty acids increased.

In the growth assay (Table 3), no differences in ADG, ADFI, or F/G were detected from d 0 to 5 (P>.30) or d 5 to 19 (P>.11). However, for d 19 and 33, ADG tended to increase (P<.06) and F/G decreased (P<.01) with the fat-added treatments versus the control.

Overall, ADG was not affected (P>.15), but F/G was improved (P<.04) with the addition of fat to the diet. No differences occurred in ADG or F/G as concentration of free fatty acids increased (P>.16). Also, no differences were observed in digestibility of DM or GE among the dietary treatments (P>.14). Also, the digestibility of long-chain unsaturated fatty acids, long-chain saturated fatty acids, and total fat were greater (P<.001) for the fat-added treatments compared to control, but fatty acid digestibility was not affected (P>.17) by concentration of free fatty acids in the diet.

In conclusion, as much as 53% free fatty acids in choice white grease did not adversely affect piglet performance. Thus, concentration of free fatty acids, if they are not otherwise damaged or rancid is not an acceptable measure of fat quality.

Table 1. Compositions of Diets[a]

Item, %	d 0 to 5		d 5 to 19		d 19 to 33	
	Control	Fat Added	Control	Fat Added	Control	Fat Added
Corn	22.84	22.84	44.10	44.10	47.81	47.81
Soybean meal (46.5% CP)	26.36	26.36	31.52	31.52	41.86	41.86
Dried whey	20.00	20.00	10.00	10.00	—	—
Lactose	10.00	10.00	—	—	—	—
Cornstarch	6.00	—	6.00	—	6.00	—
Choice white grease[b]	—	6.00	—	6.00	—	6.00
Spray-dried wheat gluten	4.00	4.00	—	—	—	—
Spray-dried plasma protein	4.00	4.00	1.00	1.00	—	—
Fish meal (menhaden)	2.00	2.00	3.00	3.00	—	—
Monocalcium phosphate (21%)	1.28	1.28	.85	.85	1.32	1.32
Limestone	.89	.89	.84	.84	1.17	1.17
L-lysine·HCl	.32	.32	.25	.25	.05	.05
D,L-methionine	.19	.19	.14	.14	.05	.05
L-threonine	.08	.08	.10	.10	—	—
Salt	.25	.25	.30	.30	.35	.35
Vitamin premix	.25	.25	.25	.25	.25	.25
Mineral premix	.15	.15	.15	.15	.15	.15
Antibiotic[c]	1.00	1.00	1.00	1.00	1.00	1.00
Zinc oxide	.32	.32	.25	.25	—	—
Copper sulfate	—	—	—	—	.09	.09
Chromic oxide	—	—	.25	.25	—	—

[a]Diets were formulated to: 1.7% lysine, .9% Ca, and .8% P for d 0 to 5; 1.55% lysine, .8% Ca, and .7% P for d 5 to 19; and 1.4% lysine, .8% Ca, and .7% P for d 19 to 33.

[b]Choice white grease with 0, 872, 1,752, and 2,248 lipase units/gram of fat.

[c]Provided 150 g of apramycin per ton of feed for d 0 to 19 and 50 g of carbox per ton of feed for d 19 to 33.

Table 2. Chemical Analysis of Choice White Grease

	Lipase Units/G of Choice White Grease			
Item	0	872	1,752	2,248
Free fatty acids, %	2	18	35	53
Peroxide value, mEq/kg	1	1	1	1
p-anisidine value	5.2	4.9	5.0	5.6
Total M.I.U., %[a]	1.17	2.56	2.85	3.34
Moisture, %	.14	1.58	1.85	2.38
Insoluble impurities, %	.01	.01	.03	.02
Unsaponifiable matter, %	1.02	.97	.97	.94
Iodine value	61.2	61.2	60.5	62.7
Unsaturated:saturated ratio	1.49	1.50	1.44	1.52
Fatty acids, % of sample[b]				
C8:0[c]	.00	.00	.00	.00
C10:0	.00	.00	.00	.00
C12:0	.26	.24	.24	.23
C14:0	2.07	2.12	2.11	2.03
C16:0	25.48	25.48	25.78	25.12
C16:1	3.23	3.33	3.19	3.40
C18:0	11.80	11.63	12.31	11.73
C18:1	48.06	48.02	47.11	47.28
C18:2	7.33	7.31	7.33	8.14
C18:3	.57	.57	.63	.77

[a]Moisture, insoluble impurities, and unsaponifiable matter.

[b]Fatty acids determined by gas chromatography as derivatized fatty acid methyl esters.

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

Table 3. Effects of Free Fatty Acid Concentration on Growth Performance and Digestibility of Nutrients in Weanling Pigs[a]

							Probability			
		Free Fatty Acid Concentration, %						Free Fatty Acid Effects		
Item	No Added Fat	2	18	35	53	SE	No Added Fat vs Others	Linear	Quadratic	Cubic
d 0 to 5										
ADG, lb	.58	.59	.62	.61	.65	.04	—[c]	—	—	—
ADFI, lb	.55	.56	.59	.58	.60	.04	—	—	—	—
F/G	.95	.95	.96	.96	.92	.05	—	—	—	—
d 5 to 19										
ADG, lb	.86	.84	.87	.81	.83	.04	—	—	—	—
ADFI, lb	1.32	1.24	1.29	1.28	1.28	.03	.11	—	—	—
F/G	1.53	1.47	1.48	1.58	1.54	.05	—	—	—	—
d 19 to 33										
ADG, lb	1.39	1.49	1.44	1.44	1.50	.03	.06	—	.11	—
ADFI, lb	2.31	2.13	2.20	2.24	2.23	.06	.11	—	—	—
F/G	1.66	1.43	1.53	1.56	1.49	.05	.01	—	.09	—
d 0 to 33										
ADG, lb	1.04	1.08	1.07	1.05	1.09	.02	—	—	—	—
ADFI, lb	1.62	1.51	1.57	1.58	1.58	.02	.02	.04	—	—
F/G	1.56	1.40	1.47	1.50	1.45	.04	.04	—	—	—
Apparent Digestibility, %										
DM	79.9	77.3	78.1	80.0	79.1	1.0	—	.14	—	—
GE	77.6	75.174.6	76.9	78.6	76.3	1.6	—	—	—	—
N	76.4	73.3	76.3	78.5	76.0	1.3	—	—	.10	—
Total fat[b]	66.4		74.1	77.7	74.7	2.2	.001	—	—	—
Long-chain unsaturated		77.9								
	69.7		79.2	81.7	79.4	2.2	.001	—	—	—
fatty acids		62.8								
Long-chain saturated	51.0	89.4	63.3	68.9	65.2	3.0	.001	—	—	—
fatty acids	91.8		89.9	91.5	89.4	.9	.11	—	—	—
Medium-chain fatty acids										

[a]A total of 125 pigs (five pigs per pen and five pens per treatment) with an average initial BW of 13.7 lb.

[b]Determined by gas chromatography as derivatized fatty acid methyl esters.

[c]P>.15.

EFFECTS OF RANCIDITY IN CHOICE WHITE GREASE ON GROWTH PERFORMANCE AND NUTRIENT DIGESTIBILITY IN WEANLING PIGS

J. M. DeRouchey, J. D. Hancock, R. H. Hines, H. Cao, C. A. Maloney, D. W. Dean, D. J. Lee, and J. S. Park

Summary

Our data suggest that adding slightly rancid choice white grease with peroxide values of 40 mEq/kg and less and p-anisidine values of 10.6 and less to diets will not decrease growth performance in nursery pigs. However, reduced feed intake and, thus, reduced rate of gain occurred at greater peroxide and p-anisidine values.

(Key Words: Pigs, Fat Quality, Rancidity.)

Introduction

The addition of fat to nursery diets is a common practice. Research efforts about fat utilization by weanling pigs mainly has been focused on the effects of essential fatty acids, unsaturated:saturated ratios, chain length of the fatty acids, and age of the pigs when fat was added to the diet. Unfortunately, little attention has been given to the effects of fat quality, such as rancidity, on nursery pig performance. Our objective was to determine the effects of rancidity in choice white grease on growth performance and nutrient digestibility in weanling pigs.

Procedures

One hundred fifty (lines C 22 × 326, PIC, Franklin, KY) weanling pigs (average initial BW of 15.0 lb) were used in a 35-d assay. The pigs were weaned and allotted by BW, sex, and ancestry to six treatments. Initial BW was the blocking criterion. There were five pigs per pen with six pens per treatment. The diets (Table 1) were formulated to 1.70% lysine for d 0 to 7, 1.55% lysine for d 7 to 21, and 1.40% lysine for d 21 to 35 and met or exceeded all nutrient requirements as defined by NRC (1998). Treatments were a corn-soybean meal-based control with no added fat, 6% choice white grease, and 6% choice white grease heated at 176°F with O_2 gas bubbled through fat at a rate of 849 mL/min for 5, 7, 9, and 11 d. After exposure to the various degrees of thermal and oxidative stress, aliquots of the fat were stabilized with an antioxidant at 1 g/kg of fat. Also, fat was stored in a cool room (50°F) to help ensure the desired development of rancidity for each fat treatment. Chemical analyses of the grease were conducted to determine changes over the 11 days of stress.

The pigs were housed in an environmentally controlled building. Each pen had a self-feeder and nipple water to allow ad libitum consumption of feed and water. Pigs and feeders were weighed on d 7, 21, and 35 to allow calculation of ADG, ADFI, and F/G.

Statistical analyses were performed using the GLM procedure of SAS. Polynomial regression was used to determine shape of the response to increasing rancidity with pen used as the experimental unit.

Results and Discussion

Analyses of the choice white grease (Table 2) indicated that thermal and oxidative stress increased the peroxide value until d 7 (105 mEq/kg), and then the hydroperoxides decomposed to concentrations similar to that of the untreated fat (i.e., 1 mEq/kg). The p-anisidine test was used to determine the aldehyde content of the choice white grease. This value also increased until d 7 and then decreased as thermal and oxidative exposure was increased to 9 and 11 d. Therefore, peroxide and p-anisidine determi-

nations are reliable indicators of fat quality only with low to moderate levels of auto-oxidation.

Moisture, insoluble impurities, and unsaponifiable matter were not changed as the fat became more rancid. However, iodine values and unsaturated:saturated fatty acid ratios decreased with increasing rancidity, indicating that as fats become rancid, their fatty acids become more saturated. Among the fatty acids, the percentage of C16:0 increased most, whereas percentages of C18:1 and C18:2 decreased the most.

In the pig growth assay (Table 3), no differences (P>.14) were detected in growth performance for d 0 to 7. However, for d 21 to 35 and overall (d 0 to 35), efficiency of gain was improved when fat was added to the diets (P<.04). Also, for d 7 to 21, 21 to 35, and overall, ADG (P<.01) and ADFI (P<.09) were decreased as rancidity of fat was increased. These reductions in feed intake and rate of gain were pronounced only with more than 5 d of thermal and oxidative stress (i.e., peroxide values >40 mEq/kg).

Digestibility of DM decreased for diets containing grease exposed to 5 and 7 d of stress and then increased for diets containing grease exposed for up to 11 d (quadratic effect, P<.04). Furthermore, digestibilities of GE and N were unaffected (P>.13) as the added fat became more rancid. Thus, rancidity of the fat did not appear to affect digestibility of major nutrient classes.

Digestibilities of long-chain unsaturated fatty acids, long-chain saturated fatty acids, and total fat were greater (P<.001) for the fat-added treatments compared to the no-added fat control. However, no differences (P>.10) for fatty acid digestibility occurred among the fat-added treatments, even with the greatest thermal and oxidative challenge (i.e., 11 d). Thus, the negative effects of rancidity on piglet growth do not appear to result from decreased nutrient digestibility or utilization. Rather, the effect seems to result from decreased feed intake.

In summary, fat that is added to diets for nursery pigs should be monitored for rancidity to avoid decreased feed intake and, thus, decreased ADG. However, our data demonstrate that commonly used measures of rancidity (i.e., peroxide and p-anisidine values) are unreliable indicators of rancidity in substantially damaged fats. Thus, it is essential to know the history of your fat source and the reliability of your supplier to have confidence in the quality of fat that is fed.

Table 1. Compositions of Diets[a]

	d 0 to 7		d 7 to 21		d 21 to 35	
Item, %	Control	Fat Added	Control	Fat Added	Control	Fat Added
Corn	22.84	22.84	44.10	44.10	47.81	47.81
Soybean meal (46.5% CP)	26.36	26.36	31.52	31.52	41.86	41.86
Dried whey	20.00	20.00	10.00	10.00	—	—
Lactose	10.00	10.00	—	—	—	—
Cornstarch	6.00	—	6.00	—	6.00	—
Choice white grease[b]	—	6.00	—	6.00	—	6.00
Spray-dried wheat gluten	4.00	4.00	—	—	—	—
Spray-dried plasma protein	4.00	4.00	1.00	1.00	—	—
Fish meal (menhaden)	2.00	2.00	3.00	3.00	—	—
Monocalcium phosphate (21%)	1.28	1.28	.85	.85	1.32	1.32
Limestone	.89	.89	.84	.84	1.17	1.17
L-lysine·HCl	.32	.32	.25	.25	.05	.05
DL-methionine	.19	.19	.14	.14	.05	.05
L-threonine	.08	.08	.10	.10	—	—
Salt	.25	.25	.30	.30	.35	.35
Vitamin premix	.25	.25	.25	.25	.25	.25
Mineral premix	.15	.15	.15	.15	.15	.15
Antibiotic[c]	1.00	1.00	1.00	1.00	1.00	1.00
Zinc oxide	.32	.32	.25	.25	—	—
Copper sulfate	—	—	—	—	.09	.09
Chromic oxide	—	—	.25	.25	—	—

[a]Diets were formulated to: 1.7% lysine, .9% Ca, and .8% P for d 0 to 7; 1.55% lysine, .8% Ca, and .7% P for d 7 to 21; and 1.4% lysine, .8% Ca, and .7% P for d 21 to 35. [b]Choice white grease with 0, 5, 7, 9, and 11 d of thermal (heated at 176°F) and oxidative stress (O_2 gas at 849 mL/min). [c]Provided 150 g of apramycin per ton of feed for d 0 to 21 and 50 g of carbox per ton of feed for d 21 to 35.

Table 2. Chemical Analysis of Choice White Grease

	Day of Thermal and Oxidative Exposure				
Item	0	5	7	9	11
Peroxide value, mEq/kg	1	40	105	1	1
p-anisidine value	2.5	10.6	20.5	11.1	7.5
Free fatty acids, %	2	2	2	3	3
Total M.I.U., %[a]	1.34	1.09	1.30	1.33	1.26
Moisture, %	.14	.06	.13	.11	.24
Insoluble impurities, %	.01	.01	.01	.01	.01
Unsaponifiable matter, %	1.19	1.02	1.16	1.21	1.01
Iodine value	63.5	60.9	58.7	54.6	55.2
Unsaturated:saturated ratio	1.51	1.28	1.28	1.15	1.19
Fatty acids, % of sample[b]					
C8:0[c]	.00	.00	.00	.00	.00
C10:0	.00	.00	.00	.00	.00
C12:0	.08	.06	.02	.05	.04
C14:0	1.50	1.45	1.40	1.55	1.45
C16:0	30.30	32.50	32.56	35.98	34.19
C16:1	3.68	3.33	3.37	3.23	3.38
C18:0	7.54	9.28	9.44	8.49	9.44
C18:1	46.02	44.01	43.78	43.40	43.46
C18:2	9.71	8.35	8.00	5.92	6.12
C18:3	.35	.28	.58	.60	.64

[a]Total moisture, insoluble impurities, and unsaponifiable matter. [b]Determined as derivatized fatty acid methyl esters by gas chromatography. [c]Number of carbon atoms and double bonds designated to the left and right of the colon, respectively.

Table 3. Effects of Rancidity on Growth Performance and Digestibility of Nutrients for Weanling Pigs[a]

		Days of Thermal and Oxidative Stress						Probability				
									Rancidity Effects			
Item	No Added Fat	0	5	7	9	11	SE	No Added Fat vs Others	Linear	Quadratic	Cubic	Quartic
d 0 to 7												
ADG, lb	.54	.55	.55	.57	.57	.52	.03	—[c]	—	—	—	—
ADFI, lb	.63	.69	.68	.65	.67	.66	.03	—	—	—	—	—
F/G	1.17	1.25	1.24	1.14	1.18	1.27	.05	—	—	.15	.14	—
d 7 to 21												
ADG, lb	.96	1.08	1.08	.99	.99	.94	.03	.13	.003	—	—	—
ADFI, lb	1.34	1.45	1.45	1.31	1.28	1.28	.05	—	.01	—	—	—
F/G	1.39	1.34	1.34	1.32	1.29	1.36	.05	—	—	—	—	—
d 21 to 35												
ADG, lb	1.56	1.54	1.54	1.49	1.53	1.46	.04	—	—	—	—	—
ADFI, lb	2.46	2.33	2.33	2.16	2.15	2.13	.04	.001	.001	—	.07	—
F/G	1.58	1.51	1.51	1.45	1.41	1.46	.04	.03	.09	—	.13	—
d 0 to 35												
ADG, lb	1.12	1.16	1.16	1.11	1.12	1.05	.03	—	.01	—	—	—
ADFI, lb	1.64	1.65	1.62	1.52	1.50	1.50	.03	.03	.001	—	—	—
F/G	1.46	1.42	1.40	1.37	1.34	1.43	.03	.04	—	—	—	—
Apparent digestibility, %												
DM	82.9	83.6	81.9	79.6	79.6	83.3	1.2	—	—	.04	.06	—
GE	82.6	81.8	80.5	79.5	78.4	82.2	1.5	—	—	—	—	—
N	75.5	76.1	78.0	74.1	74.9	78.3	2.1	—	—	—	.13	—
Total fat[b]	72.6	84.5	81.3	84.9	81.8	84.5	1.7	.001	—	—	—	.10
Long-chain unsaturated fatty acids	78.5	89.3	87.8	88.8	87.6	89.5	.9	.001	—	—	—	—
Long-chain saturated fatty acids	54.7	76.0	70.6	78.5	74.0	76.5	2.8	.001	—	—	—	.10
Medium-chain fatty acids	93.4	91.7	91.0	92.6	89.0	93.6	1.2	—	—	—	—	.03

[a]A total of 150 pigs (five pigs per pen and five pens per treatment) with an average initial BW of 15.0 lb.

[b]Determined as derivatized fatty acid methyl esters by gas chromatography.

[c]P>.15.

EFFECTS OF INCREASING L-LYSINE HCl IN CORN-SOYBEAN MEAL DIETS ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF GROWING-FINISHING GILTS [1]

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

Summary

An experiment using 1,200 gilts (65 to 260 lb) was conducted to determine the effects of increasing L-lysine HCl in corn-soybean meal diets on growth performance and carcass characteristics. The dietary treatments consisted of a control diet with no added L-lysine HCl and six increasing levels of L-lysine HCl (1, 2, 3, 4, 5, and 6 lb/ton) replacing the lysine provided by soybean meal. A negative control treatment was used to ensure that dietary lysine was not above required levels. Increasing L-lysine HCl above 3 lb/ton decreased ADG and increased F/G. Backfat was increased and FFLI decreased with increasing L-lysine HCl in the diet, and the greatest responses occurred at levels above 3 lb/ton. These results indicate that no more than 3 lb/ton (.15%) of L-lysine HCl should be added to corn-soybean meal diets for growing-finishing pigs unless other synthetic amino acids are added to avoid deficiencies that compromise growth performance.

(Key Words: Lysine, Corn, Finishing Pigs.)

Introduction

L-lysine HCl is a synthetic amino acid that can economically replace the lysine provided by soybean meal in diets for growing-finishing pigs. Although adding more than the recommended 3 lb/ton of synthetic lysine will decrease diet costs, there is a potential that deficiencies of other amino acids will limit pig performance. Two previous studies conducted by De La Llata et al. under university research settings demonstrated that increasing the amount of synthetic lysine from 0 or 3 lb/ton to 4.5 or 6 lb/ton in corn-soybean meal- and sorghum-soybean meal-based diets for growing–finishing pigs decreased performance and carcass characteristics. Therefore, the objective of this experiment was to determine how much synthetic lysine could be added to growing-finishing pig diets without adversely affecting growth performance and carcass traits of pigs reared under commercial conditions.

Procedures

A total of 1,200 gilts (PIC C22 × 337) with an initial weight of 64 lb was used in this experiment. Pigs were allotted to one of eight dietary treatments in a randomized complete block design with 25 pigs/pen and 6 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 was a double curtain-sided, deep-pit barn that operated on manual ventilation during the summer and on automatic ventilation during the winter.

[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.

The treatments were corn-soybean meal-based diets fed in four phases (Tables 1, 2, 3, and 4) and consisted of a positive control diet with no added L-lysine HCl and six increasing levels of L-lysine HCl (1, 2, 3, 4, 5, and 6 lb/ton) replacing the lysine provided by soybean meal. A negative control treatment with no added L-lysine HCl was formulated to contain .10% less total lysine than the other treatments to ensure that dietary lysine was not above required levels. Vitamin and trace mineral levels were similar to KSU recommendations.

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 individual carcass data collection. 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. The experiment was conducted from August to December, 1999.

Analysis of variance was used to analyze the data as a randomized complete block design using GLM procedures of SAS with linear and quadratic polynomial contrasts.

Results and Discussion

The growth performance and carcass data are presented in Table 5. In general, the negative control resulted in slower growth and poorer feed conversion than the 0 lb added L-lysine HCl treatment for each phase. Also, increasing the amount of L-lysine HCl resulted in a linear decrease in growth and an increase in feed efficiency.

For the overall experiment, ADG decreased (linear, $P<.01$), F/G increased (quadratic $P<.03$), and ADFI was not affected ($P>.88$) by increasing L-lysine HCl from 0 to 6 lb/ton. Pigs fed the negative control diet had decreased ($P>.01$) ADG, increased ($P<.01$) F/G, and similar ($P>.90$) ADFI compared to those fed the 0 lb/ton treatment.

Increasing L-lysine HCl did not affect ($P>.20$) carcass yield, but increased (linear $P<.01$) backfat depth and decreased (linear $P<.02$) loin eye depth, percent lean, and fat-free lean index (FFLI). Carcass yield, loin eye depth, percent lean and FFLI were decreased ($P<.05$) in the negative control compared to the 0 lb/ton treatment.

The significant quadratic responses observed during phases 2 and 4 and for the overall experiment indicate that growth performance is affected adversely when more than 3 lb/ton of L-lysine HCl is added to the diet. The linear responses observed during phases 1 and 3 showed a numerical decrease in ADG and an increase in F/G with more than 3 lb/ton of L-lysine HCl. Similarly, the carcass characteristics were influenced negatively by the addition of more than 3 lb/ton of L-lysine HCl.

The decrease in performance observed for the negative control indicates that the dietary treatments were not formulated above the required levels. This is important, because producers using growing-finishing diets containing levels beyond 3 lb/ton of L-lysine HCl might observe that growth performance is not adversely affected, which might indicate that the diet are over-formulated in the first place.

In summary, in agreement with previous research, this experiment indicated that no more than 3 lb/ton of L-lysine HCl (.15%) should be added to corn-soybean meal-based diets for growing-finishing pigs to avoid deficiencies of other amino acids that may limit growth performance.

Table 1. Diet Compositions for Phase 1 (60 to 100 lb)

		L-Lysine HCl, lb/ton						
Ingredient, %	Neg. Control	0	1	2	3	4	5	6
Corn	58.55	54.84	56.22	57.61	59.00	60.49	61.85	63.24
Soybean meal, 46.5%	32.55	36.31	34.88	33.44	32.00	30.46	29.02	27.59
Choice white grease	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Monocal. phosphate	1.33	1.30	1.30	1.30	1.30	1.30	1.33	1.33
Limestone	1.00	.98	.98	.98	.98	.98	.98	.98
Salt, vit. & trace minerals	.58	.58	.58	.58	.58	.58	.58	.58
L-Lysine HCl	0	0	.05	.1	.15	.20	.25	.30
Calculated Analysis								
Lysine, %	1.15	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Protein, %	20.1	21.5	21	20.4	19.9	19.3	18.8	18.1
ME, Kcal/lb	1623	1623	1623	1623	1623	1623	1623	1623
Calcium, %	.74	.74	.74	.74	.74	.74	.74	.74
Phosphorus, %	.66	.66	.66	.66	.66	.66	.66	.66

Table 2. Diet Compositions for Phase 2 (100 to 150 lb)

		L-Lysine HCl, lb/ton						
Ingredient, %	Neg. Control	0	1	2	3	4	5	6
Corn	66.57	62.64	64.00	65.38	66.77	68.13	69.49	70.87
Soybean meal, 46.5%	24.68	28.66	27.23	25.79	24.36	22.92	21.49	20.05
Choice white grease	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Monocal. phosphate	1.23	1.20	1.20	1.20	1.20	1.20	1.23	1.23
Limestone	0.95	0.93	0.95	0.95	0.95	0.98	0.98	0.98
Salt, vit. & trace minerals	.58	.58	.58	.58	.58	.58	.58	.58
L-Lysine HCl	0	0	.05	.1	.15	.20	.25	.30
Calculated Analysis								
Lysine, %	.94	1.04	1.04	1.04	1.04	1.04	1.04	1.04
Protein, %	17.1	18.7	18.1	17.6	17.0	16.4	15.9	15.3
ME, Kcal/lb	1626	1626	1626	1626	1626	1626	1626	1626
Calcium, %	.69	.69	.69	.69	.69	.69	.69	.69
Phosphorus, %	.61	.61	.61	.61	.61	.61	.61	.61

Table 3. Diet Compositions for Phase 3 (150 to 200 lb)

		L-Lysine HCl, lb/ton						
Ingredient, %	Neg. Control	0	1	2	3	4	5	6
Corn	74.99	71.18	72.57	73.95	75.31	76.67	78.06	79.42
Soybean meal, 46.5%	16.45	20.28	18.84	17.41	15.97	14.54	13.10	11.67
Choice white grease	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Monocal. phosphate	1.13	1.10	1.10	1.10	1.10	1.13	1.13	1.13
Limestone	0.93	0.93	0.93	0.93	0.95	0.95	0.95	0.98
Salt, vit. & trace minerals	.51	.51	.51	.51	.51	.51	.51	.51
L-Lysine HCl	0	0	.05	.1	.15	.20	.25	.30
Calculated Analysis								
Lysine, %	.71	.81	.81	.81	.81	.81	.81	.81
Protein, %	14.0	15.5	14.9	14.4	13.8	13.3	12.7	12.1
ME, Kcal/lb	1630	1630	1630	1630	1630	1630	1630	1630
Calcium, %	.64	.64	.64	.64	.64	.64	.64	.64
Phosphorus, %	.55	.55	.55	.55	.55	.55	.55	.55

Table 4. Diet Compositions for Phase 4 (200 to 250 lb)

		L-Lysine HCl, lb/ton						
Ingredient, %	Neg. Control	0	1	2	3	4	5	6
Corn	82.24	78.46	79.82	81.20	82.67	84.03	85.42	86.78
Soybean meal, 46.5%	9.32	13.16	11.72	10.29	8.74	7.30	5.87	4.43
Choice white grease	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Monocal. phosphate	1.08	1.05	1.05	1.05	1.05	1.08	1.08	1.08
Limestone	0.85	0.83	0.85	0.85	0.88	0.88	0.88	0.90
Salt, vit. & trace minerals	.51	.51	.51	.51	.51	.51	.51	.51
L-Lysine HCl	0	0	.05	.1	.15	.20	.25	.30
Calculated Analysis								
Lysine, %	.52	.62	.62	.62	.62	.62	.62	.62
Protein, %	11.3	12.8	12.2	11.7	11.1	10.5	10.0	9.3
ME, Kcal/lb	1631	1631	1631	1631	1631	1631	1631	1631
Calcium, %	.58	.58	.58	.58	.58	.58	.58	.58
Phosphorus, %	.51	.51	.51	.51	.51	.51	.51	.51

Table 5. Effects of Increasing L-Lysine HCl on Growth Performance and Carcass Characteristics of Growing-Finishing Gilts[a]

		L-Lysine HCl, lb/ton							Contrast P <			
Item	Neg. Control	0	1	2	3	4	5	6	Neg. vs 0	Linear	Quadratic	CV, %
Day 0 to 27												
ADG, lb	1.68	1.77	1.80	1.76	1.78	1.70	1.72	1.69	0.10	0.02	0.59	5.3
ADFI, lb	3.09	3.07	3.08	3.07	3.08	3.16	3.14	3.14	0.88	0.09	0.87	3.5
F/G	1.83	1.74	1.71	1.75	1.74	1.87	1.83	1.86	0.10	0.01	0.55	5.2
Day 27 to 54												
ADG, lb	1.74	1.88	1.90	1.94	1.90	1.84	1.79	1.72	0.06	0.01	0.05	7.0
ADFI, lb	4.54	4.51	4.68	4.57	4.49	4.68	4.59	4.66	0.91	0.48	0.79	5.1
F/G	2.62	2.41	2.47	2.37	2.37	2.54	2.57	2.72	0.02	0.01	0.02	5.9
Day 54 to 82												
ADG, lb	1.70	1.82	1.86	1.82	1.81	1.71	1.62	1.63	0.04	0.01	0.13	5.5
ADFI, lb	4.68	4.75	4.71	4.73	4.69	4.71	4.72	4.90	0.57	0.34	0.15	4.4
F/G	2.75	2.61	2.53	2.60	2.61	2.76	2.93	3.00	0.12	0.01	0.02	5.7
Day 82 to 116												
ADG, lb	1.56	1.62	1.60	1.54	1.58	1.46	1.47	1.54	0.38	0.05	0.28	8.5
ADFI, lb	5.59	5.61	5.57	5.46	5.55	5.50	5.33	5.46	0.95	0.22	0.82	6.1
F/G	3.60	3.46	3.51	3.57	3.55	3.77	3.62	3.56	0.36	0.20	0.29	7.5
Overall												
ADG, lb	1.66	1.76	1.78	1.75	1.76	1.66	1.64	1.64	0.01	0.01	0.19	3.2
ADFI, lb	4.52	4.54	4.56	4.50	4.50	4.54	4.46	4.55	0.90	0.74	0.52	3.0
F/G	2.72	2.57	2.56	2.57	2.56	2.72	2.72	2.78	0.01	0.01	0.03	2.6
Packing Plant Data[b]												
Carcass wt.	199.7	204.4	206.3	204.1	205.1	201.6	202.2	198.5	.19	.04	.32	3.0
Yield, %	75.3	76.9	75.6	75.9	76.4	76.3	75.9	75.9	0.01	0.26	0.58	.9
Backfat, in.	0.70	0.66	0.66	0.68	0.67	0.69	0.72	0.70	0.10	0.01	0.59	4.7
Loin depth, in.	2.22	2.36	2.32	2.25	2.32	2.35	2.28	2.22	0.01	0.02	0.27	3.0
Percent lean	54.78	55.80	55.61	55.25	55.51	55.29	54.67	54.78	0.01	0.01	0.90	1.1
FFLI	50.07	50.53	50.49	50.35	50.40	50.14	49.84	50.06	0.08	0.01	0.81	0.8

[a]One thousand two hundred (PIC) growing-finishing gilts, initial weight 65 lb.

[b]Carcass weight used as a covariate to analyze the backfat, loin depth, percent lean, and FFLI data.

INFLUENCE OF DIETARY NIACIN ON FINISHING PIG PERFORMANCE AND MEAT QUALITY

D. E. Real, J. L. Nelssen, M. D. Tokach, R. D. Goodband, S. S. Dritz[1], J. A. Unruh, J. M. DeRouchey, J. C. Woodworth, M. J. Webster, B. W. James, and E. Alonso[2]

Summary

One hundred forty-four finishing pigs were used to determine the influence of added dietary niacin on their growth performance and meat quality. Gilts grew slower, ate less, and were more efficient than barrows for the entire growth performance period. Increasing dietary niacin levels to 25 g/ton increased ADG in gilts for the first 25 days, but decreased ADG for barrows. No other interactions occurred. From d 25 to 62, ADFI tended to increase for pigs fed up to 100 g/ton niacin, whereas pigs fed 500 g/ton niacin ate less. Dietary niacin level did not significantly affect carcass yield or quality characteristics.

(Key Words: Niacin, Finishing Pigs, Meat Quality.)

Introduction

Niacin has long been accepted as an essential vitamin for swine diets. However, the optimal level of inclusion for finishing pigs has been the subject of considerable debate. According to a 1997 survey of vitamin inclusion rates, the overall average inclusion rate for niacin was 21 g/ton. The average for the 25% of the companies with the highest inclusion rates was 32 g/ton. The average of the lowest 25% of the companies was only 12 g/ton. Vitamin requirements of pigs are influenced by many factors, including the health status, previous nutrition, vitamin levels in other ingredients in the diet, and level of metabolic precursors in the diet. We are unaware of any research to determine the influence of niacin on meat quality of finishing pigs. An effect of niacin on serotonin levels would indicate a potential calming influence, which could improve meat quality of finishing pigs fed higher dietary levels of niacin. Modern lean genetics have lead to a particular problem with aggression in the growing-finishing phase and on the packer floor. Because of the lack of information concerning the influence of niacin on meat quality and the wide range of supplementation rates in the commercial industry, we conducted an experiment to determine the influence of niacin level in finishing diets on pig performance and meat quality characteristics.

Procedures

One hundred forty-four crossbred barrows and gilts, initially 112.8 lb, were used in this experiment. Niacin was added to a control diet (no added niacin) at rates of 12.5, 25, 50, 100, or 500 g/ton. Pigs were blocked by weight and fed one of the six dietary treatments.

Diets (Table 1) were fed in two phases. Phase I was fed from d 0 to 25 and formulated to contain 1.0% lysine; phase II was fed from d 25 to 62 and was formulated to contain 0.75% lysine. The diets were corn-soybean meal based and fed in meal form. The pigs were housed with two pigs per pen in an environmentally controlled finishing barn with 4-ft × 4-ft slatted-floor pens. Each treatment included two pigs per pen and 12 pigs per treatment (six pens of gilts and six pens of barrows). Pigs were provided ad libitum access to feed and water. Pigs and feeders were weighed to determine ADG, ADFI, and F/G. Pen served as the experimental unit for all statistical analysis.

---

[1]Food Animal Health and Management Center.

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

One pig from each pen (closest to 240 lb) was slaughtered at the Kansas State University Meats Laboratory when the mean weight of all pigs was 240 lb. An entire block was removed from the experiment at the same time. At 45 min and 1 h postmortem, longissimus muscle (LM) pH and temperature were recorded. At 24 h postmortem, carcasses were ribbed, and one chop was removed (9th rib chop) and allowed to bloom for 30 minutes. Ultimate pH and temperature of the LM were measured at the tenth rib. Then, a two-person panel assigned visual color, marbling, and firmness scores for tenth rib LM. Longissimus muscle color was evaluated on a scale of 1 to 5 with 1 representing a muscle that was pale pinkish-gray and 5 representing a dark-purplish red color. Marbling was evaluated on a scale of 1 to 5 with 1 being practically devoid and 5 being moderately abundant or greater. Longissimus muscle firmness was evaluated on a scale of 1 to 3 with 1 being soft and exudative and 3 being firm and moist.

Immediately thereafter, Minolta color spectrophotometry data (CIE L*, a*, and b* values) were obtained in duplicate from the same chop. These values then were used to calculate A:B ratio, hue angle, and saturation index. The Minolta L* value represents the lightness of the sample. Longissimus muscles with a higher L* value would be lighter in color. Minolta a* values are chromatic coordinates representing a change from green to red color. A higher a* value indicates a sample with more red color. Minolta b* values are also chromatic coordinates, representing a change in color from blue to yellow. The higher the b* value, the more yellow the sample is in color. The A:B ratio indicates a change in redness. The higher the ratio, the redder the color. The hue angle represents the change from red to an orange color; therefore, a larger hue angle corresponds to less red color in the sample. The chroma or the total color, of the sample is expressed as the saturation index. The greater the value of the saturation index, the more intense the color of the sample.

The chops then were dissected, a 1-cu in. sample was taken to determine drip loss, and a .5 g sample was taken to determine water holding capacity (WHC). Samples were weighed and suspended on a fishhook inside a sealed container at 6°C for 24 hours. Then they were removed from the sealed containers and weighed again to determine percent drip loss. Water holding capacity was determined by the Carver press analysis and is expressed as a percent of meat:water ratio.

The data from this experiment were analyzed by the proc mixed procedure of SAS as a split-plot design with dietary niacin level as whole plot and sex as the subplot. The model included contrasts for linear and quadratic effects of increasing dietary niacin.

Results and Discussion

For the entire growth portion of the study, barrows had greater ADG, ADFI, and F/G than gilts ($P<.01$;Table 2). From d 0 to 25, a sex × treatment interaction affected ADG ($P<.04$;Table 2). Increasing dietary niacin to 25 g/ton increased ADG of gilts, but decreased ADG of barrows. Average daily feed intake and F/G decreased linearly ($P<.03$; $P<.05$, respectively) during this period. This response was caused by the lower intake for pigs fed 500 g/ton, because no differences in ADFI and F/G were apparent for pigs fed 0 to 100 g/ton niacin. From d 25 to 62, pigs fed up to 100 g/ton niacin tended to have higher ADFI ($P<.09$), but poorer F/G ($P<.11$) than pigs fed lower levels of niacin. However, pigs fed 500 g/ton niacin had lower ADFI (quadratic, $P<.005$) and lower ADG (quadratic, $P<.03$) similar to that of control pigs. Overall, ADFI tended to increase ($P<.08$;quadratic $P<.007$) along with feed efficiencies ($P<.11$; quadratic $P<.007$) for pigs fed up to 100 g/ton niacin, but then pigs fed 500 g/ton niacin had similar feed intakes and F/G as control pigs.

No differences (P<.10) in live wt or dressing percent occurred among niacin rates or between sexes (Table 3). Hot and cold carcass weights both decreased linearly (P<.05, P<.06, respectively). However, this can be attributed to the lower weights for pigs fed 500 g/ton. Essentially, pigs fed niacin up to 100 g/ton had similar carcass weights as control pigs. Niacin had no other effects on any of these carcass parameters. Sex had a significant effect on shrink loss (P<.001), because percent of cooler shrink was higher for gilts than for barrows. Gilts also had lower average and tenth rib backfat measurements (P<.001), shorter carcasses (P<.001), larger loin eyes (P<.001), and a higher percent lean (P<.001).

Subjective quality measurements on the LM showed no differences, only trends among treatments (Table 4). Even so, LMs from pigs fed niacin tended to have more reddish-pink color (P<.14) than those from pigs fed no added niacin. However, sex differences were observed. Carcasses of gilts had a more reddish pink color (P<.01), less marbling (P<.001), and a less firm and more exudative LM (P<.001) than carcasses of barrows. Gilt carcasses also had a lower b* value (P<.01) and saturation index (P<.02) than barrow carcasses, indicating that lean from barrows had a more yellowish, intense color. Carcasses of barrows also tended to be colder at 45 min postmortem than those of gilts (P<.07), and carcasses of pigs fed increasing levels of niacin were colder at 45 min postmortem (P<.08; linear P<.06).

In conclusion, this experiment showed that niacin had minimal effects on growth performance of pigs from 110 to 250 lb, regardless of sex. This could have been because pigs were eating an average of 6.47 lb of feed, and, therefore, had sufficient niacin from soybean meal and corn to meet their requirement. However, ADFI appeared to be increased with up to 100 g/ton niacin and then was similar to controls when niacin was included at 500 g/ton.

Although carcasses from pigs fed niacin tended to have a more reddish-pink color and a firmer lean, from a muscle quality perspective, niacin had minimal effects on carcass parameters and meat quality measurements.

Further research under field conditions needs to be conducted to determine the optimal amount of niacin for pigs with a lower level of feed intake.

Table 1. Compositions of Basal Diets

	Phases	
Ingredient, %	D 0 to 25	D 25 to 62
Corn	74.31	83.53
Soybean meal (46.5%)	22.79	13.72
Limestone	0.90	0.85
Monocalcium P (21% P)	0.90	0.80
Salt	0.35	0.35
Cornstarch[a]	0.35	0.35
Vitamin premix[b]	0.15	0.15
Lysine HCl	0.15	0.15
Trace mineral premix	0.10	0.10
Total	100.00	100.00

[a]Cornstarch was replaced by niacin from nicotinic acid (Lonza) to provide 12.5, 25, 50, 100, and 500 g/ton.

[b]Vitamin premix provided 6,000,000 USP units vitamin A, 900,000 USP units vitamin D_3, 24,000 IU vitamin E, 2400 mg B_{12}, 5400 mg riboflavin, and 18,000 mg pantothenic acid.

Table 2. Growth Performance of Finishing Pigs Fed Niacin[a]

	Niacin, g/ton							Sex			Contrasts (P<)				
Item	0	12.5	25	50	100	500	SEM	F	M	SEM	Trt	Sex	Int.	Lin.	Quad.
D 0 to 25															
ADG, lb	2.48	2.49	2.48	2.54	2.49	2.49	.051	2.37	2.61	.037	.89	.001	.04	.91	.68
ADFI, lb	6.08	6.10	6.12	6.18	6.10	5.89	.116	5.60	6.56	.089	.33	.001	.25	.03	.51
F:G	2.45	2.45	2.47	2.43	2.45	2.36	.041	2.36	2.51	.025	.44	.001	.12	.05	.84
D 25 to 62															
ADG, lb	2.22	2.09	2.16	2.28	2.29	2.15	.056	2.13	2.27	.034	.10	.003	.48	.50	.03
ADFI, lb	6.42	6.72	6.74	6.90	7.14	6.56	.201	6.33	7.16	.142	.09	.001	.63	.45	.005
F:G	2.89	3.22	3.12	3.02	3.12	3.05	.102	2.98	3.16	.079	.11	.01	.94	.91	.39
D 0 to 62															
ADG, lb	2.33	2.25	2.29	2.39	2.37	2.29	.042	2.23	2.41	.027	.17	.001	.12	.56	.06
ADFI, lb	6.28	6.47	6.49	6.61	6.72	6.27	.146	6.03	6.92	.110	.08	.001	.49	.18	.007
F:G	2.70	2.87	2.84	2.77	2.83	2.74	.061	2.71	2.87	.047	.11	.001	.84	.33	.29
Trt × sex interaction[b]															
D 0 to 25															
Gilts	2.37	2.30	2.46	2.41	2.35	2.33	.067								
Barrows	2.59	2.68	2.49	2.68	2.62	2.62	.067								

[a]Values are means of 144 pigs (initially 112.8 lb) with 2 pigs/pen and 6 replicate pens per treatment.

[b]Interaction significant (P<.04); no other interactions significant (P>.05).

Table 3. Carcass Yield Characteristics of Finishing Pigs Fed Niacin

	Niacin, g/ton							Sex			Contrasts (P<)				
Item	0	12.5	25	50	100	500	SEM	F	M	SEM	Trt	Sex	Int.	Lin.	Quad.
Live wt., lb	253.7	252.0	251.3	258.5	252.8	248.5	3.08	253.4	252.2	1.72	.34	.58	.51	.15	.52
Dressing %	75.05	75.58	75.35	75.71	74.96	74.73	.417	75.10	75.36	.213	.54	.32	.23	.18	.92
Hot wt., lb	190.4	190.4	189.3	195.7	189.5	185.7	2.48	190.3	190.1	1.58	.11	.91	.16	.05	.54
Cold wt., lb	187.6	187.8	186.5	193.2	187.0	183.4	2.52	186.9	188.3	1.63	.11	.36	.16	.06	.48
Shrink loss, %	1.51	1.38	1.47	1.26	1.31	1.23	.170	1.78	.95	.118	.73	.001	.42	.27	.41
Backfat															
Tenth rib, in	.95	.89	.90	.99	.97	.90	.044	.77	1.10	.026	.46	.001	.26	.51	.25
Average, in	1.20	1.17	1.12	1.26	1.19	1.11	.040	1.09	1.27	.023	.14	.001	.85	.11	.37
Carcass length, in	32.7	32.3	32.4	32.7	32.4	32.3	.217	31.9	33.0	.145	.44	.001	.64	.47	.85
LEA, sq in.[b]	6.27	6.66	6.77	6.68	6.23	6.29	.215	7.05	5.91	.124	.28	.001	.20	.28	.63
% Lean	50.89	52.34	52.46	51.10	50.58	51.69	.763	54.36	48.66	.440	.41	.001	.20	.97	.25
Data with hot carcass weight as a covariate[a]															
Shrink loss, %	1.51	1.38	1.48	1.21	1.32	1.27	.174	.95	.95	.125	.69	.001	.49	.45	.36
Backfat															
Tenth rib, in	.95	.89	.90	.99	.97	.90	.046	.77	1.10	.026	.49	.001	.26	.51	.25
Average, in	1.20	1.17	1.12	1.26	1.19	1.16	.041	1.09	1.27	.024	.24	.001	.85	.15	.39
Carcass length, in	32.7	32.2	32.4	32.6	32.4	32.4	.230	31.9	33.0	.151	.62	.001	.66	.77	.75
LEA,sq in.[b]	6.26	6.65	6.79	6.59	6.23	6.36	.224	7.05	5.91	.124	.37	.001	.21	.47	.55
% Lean	50.88	52.34	52.46	51.10	50.58	51.69	.808	54.36	48.66	.444	.43	.001	.21	.97	.26

[a]Hot carcass weight average 190.2 lb.

[b]LEA = loin eye area.

Table 4. Carcass Quality Characteristics of Finishing Pigs Fed Niacin

	Niacin, g/ton							Sex			Contrasts (P<)				
Item	0	12.5	25	50	100	500	SEM	F	M	SEM	Trt	Sex	Int.	Lin.	Quad.
Visual color[a]	2.21	2.42	2.33	1.71	2.42	2.50	.274	2.51	2.03	.211	.14	.01	.84	.24	.74
Marbling[b]	2.21	2.71	2.79	2.67	2.58	2.58	.273	1.90	3.28	.204	.54	.001	.54	.95	.54
Firmness[c]	1.88	2.13	2.33	1.71	2.00	2.08	.169	1.82	2.22	.088	.19	.001	.36	.76	.60
Drip loss [d], %	4.49	3.85	4.26	5.91	4.64	4.78	.925	4.58	4.73	.579	.73	.84	.34	.80	.52
WHC [e], %	29.82	31.69	32.02	29.88	33.06	32.03	1.59	32.25	30.57	1.06	.56	.17	.21	.51	.33
L*[f]	54.49	54.68	53.47	53.85	54.42	53.81	.849	53.62	54.62	.490	.90	.16	.94	.69	.96
a*[f]	7.98	7.86	8.36	8.71	8.15	8.18	.344	8.11	8.30	.248	.40	.43	.13	.97	.37
b*[f]	16.67	16.75	16.90	17.16	16.87	16.91	.414	16.54	17.21	.331	.91	.01	.31	.82	.56
a*/b*[f]	.478	.468	.496	.508	.483	.483	.016	.490	.481	.009	.55	.45	.40	.95	.47
Hue angle[f]	64.51	65.01	63.72	63.14	64.28	64.23	.727	63.95	64.351	.400	.56	.46	.36	.99	.49
Saturation index[f]	18.49	18.52	18.87	19.26	18.74	18.79	.489	18.43	9.12	.394	.69	.02	.15	.87	.45
%R630/%R580[f]	2.66	2.66	2.72	2.72	2.68	2.77	.066	2.66	2.74	.038	.82	.16	.86	.26	.95
Temperature, °C															
45 min	38.18	37.58	37.98	38.00	38.37	37.12	.367	38.14	37.60	.229	.18	.07	.93	.04	.19
1 hour	36.89	36.65	37.19	37.04	37.37	36.35	.442	37.00	36.83	.255	.63	.39	.40	.24	.24
24 hour	-.03	-.26	.03	.03	.11	.01	.116	-.09	.06	.082	.20	.08	.06	.55	.10
pH															
45 min	6.40	6.36	6.39	6.31	6.29	6.41	.081	6.37	6.35	.046	.87	.87	.37	.67	.25
1 hour	6.24	6.15	6.15	6.19	6.21	6.24	.081	6.22	6.17	.044	.93	.39	.48	.56	.98
24 hour	5.44	5.49	5.49	5.46	5.49	5.48	.027	5.48	5.48	.082	.60	.87	.57	.62	.36

[a]Scoring system of 1 to 5: 2 = grayish pink;3 = reddish pink; and 4 = purplish red.

[b]Scoring system of 1 to 5: 2 = traces to slight; 3 = small to modest; and 4 = moderate to slightly abundant.

[c]Scoring system of 1 to 3: 1 = soft and exudative; 2 = slightly firm and moist; and 3 = firm and unexudative.

[d]Calculated using fishhook method.

[e]Water holding capacity calculated by the Carver press analysis.

[f]Means were derived from two sample readings per chop. 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).

EFFECTS OF CREATINE MONOHYDRATE ON FINISHING PIG GROWTH PERFORMANCE, CARCASS CHARACTERISTICS, AND MEAT QUALITY[1]

B. W. James, R. D. Goodband, J. A. Unruh, M. D. Tokach, J. L. Nelssen, P. R. O'Quinn, and B. S. Andrews

Summary

Growth performance, carcass characteristics, and meat quality were evaluated from 320 pigs fed either a control diet or diets containing added creatine monohydrate (CMH). Dietary treatments, initiated 30-d prior to slaughter (192 lb BW), consisted of: 1) a control diet; 2) control diet with 3 g CMH/pig/d for 30 d (maintenance); 3) 25 g CMH/pig/d for 5 d followed by 3 g CMH/pig/d for the next 25 d (early load); 4) or 25 g CMH/pig/d 5 d before slaughter (late load). The results from this experiment suggest that added CMH does not affect finishing pig growth performance but may increase longissimus muscle firmness and decrease drip loss at 14 d postmortem.

(Key Words: Creatine Monohydrate, Carcass Characteristics, Meat Quality.)

Introduction

Creatine is an amino acid derivative normally produced in the liver, kidney, and pancreas from glycine, arginine, and methionine. It increases the bioavailability of phosphocreatine, a molecular component necessary for the production of cellular ATP. Athletes occasionally will take a creatine supplement to enhance duration of peak performance and to reduce fatigue resulting from high-intensity exercise. Creatine supplementation has been shown to result in increased cellular hydration, which is an anabolic proliferative signal for protein synthesis. Pork quality responses observed among limited studies to date with added creatine have been variable. One source of the variation could be the amount and duration of creatine supplementation. Therefore, the objective of this experiment was to evaluate the effects of different levels and durations of creatine monohydrate (CMH) supplementation on finishing pigs' growth performance, carcass characteristics, and meat quality.

Procedures

Three hundred twenty pigs (PIC C22 × L326) were allotted by weight and equalized across treatments for gender and ancestry in a randomized complete block design. There were 10 pigs/pen and eight replicates/treatment. Pigs (initially 118 lb) were housed in a modified-open front building with 50% solid concrete and 50% concrete slat flooring. Each 6-ft × 16-ft pen had a two-hole self-feeder and a nipple waterer to allow ad libitum access to feed and water.

Pigs were fed a nutritionally adequate sorghum-soybean meal diet until 30-d preslaughter (192 lb) when dietary treatments were initiated. Experimental treatments consisted of: 1) a control diet (.65% lysine); 2) control diet with 3 g of CMH/pig/d for 30 d (maintenance); 3) 25 g of CMH/pig/d for 5 d followed by 3 g of CMH/pig/d for the next 25 d (early load); 4) or 25 g of CMH/pig/d 5 d before slaughter (late load).

[1]Appreciation is expressed to Wilke International, Lenexa, KS, for providing the creatine monohydrate.

Weights were obtained on every pig and feed disappearance was recorded on d 30, 25, 15, 10, 5, and prior to slaughter to calculate ADG, ADFI, and feed efficiency (F/G). We measured ADFI prior to the 30-d test period to determine the amount of CMH to be supplemented to provide approximately 25 or 3 g/pig/day in the treatment diets. Two pigs (closest to the average weight of all pigs, 248 lb) per pen were selected and slaughtered at the Kansas State University Meat Laboratory. Blood samples were collected at the time of slaughter to determine serum creatinine levels. Standard carcass measurements; visual analyses of longissimus muscle color, marbling, and firmness; color spectrophotometry (L*, a*, and b*); drip loss; water holding capacity; ultimate pH; and temperature were obtained for each pig at 24 h postmortem. Loins were removed from the right side of each carcass, vacuum packaged, and stored for 14 days at 39°F. Purge loss, drip loss, water-holding capacity, pH, visual analysis, and color spectrophotometry were determined again after the loins were removed from the vacuum bags and allowed 15 min for standardization. Two 1-in-thick chops were obtained from each loin and used for chemical analysis (percentage protein, lipid, moisture) and Warner-Bratzler shear force values.

Chops were cooked to an internal core temperature of 158°F. Thawed and cooked chop weights were obtained to determine percentages of thawing and cooking losses. An Instron Model 5401 compression machine with a v-blade attachment was used to obtain shear force measurements. The v-blade speed during all measurements was 5mm/min. The cores (.5-in. diameter) were taken parallel to the muscle orientation for the tenderness evaluation.

Data were analyzed as a randomized complete block. Pen was the experimental unit for growth performance data, carcass characteristics, and meat quality measurements. The GLM procedure of SAS was used for the contrasts between control vs. creatine, maintenance and early load vs. late load, and maintenance vs. early load. Hot carcass weight was used as a covariate in the statistical model for carcass analysis.

Results and Discussion

Supplementing finishing pig diets with CMH did not affect (P>.15) ADG, ADFI, or F/G during the 30-d treatment period (Table 1). Serum creatinine levels were not different among pigs fed any of the experimental diets.

Dressing percentage, shrink loss (1-(cold carcass wt/hot carcass wt)) × 100, average back fat, tenth rib fat depth, longissimus muscle area, percentage lean, heart weight, and kidney weight (Table 2) were not affected (P>.25) by feeding CMH. Visual color and marbling scores were not affected (P>.20) at 24 h or 14 d postmortem; however, the mean firmness score was greater (P<.05) at 24 h and 14 d for all pigs fed CMH postmortem than for pigs fed the control diet (Table 3 and Table 4). Longissimus muscle percentage moisture, protein, and lipid and 14-d postmortem loin purge loss and Warner-Bratzler shear force values were not affected (P >.21) by dietary treatment. Chop thawing and cooking losses were not different among treatments. Color spectrophotometry, water holding capacity, temperature, and pH at 45 min and 24 h (Table 3) were not affected by feeding CMH. Longissimus muscle drip loss percentage at 24 h postmortem was less (P<.05) for pigs fed maintenance and late load CMH compared to pigs fed early load CMH (4.06 and 4.15 vs. 5.76%). Drip loss also tended to be less (P<.09) for maintenance CMH pigs than for control pigs (4.06 vs. 5.31%). At 14 d postmortem, drip loss was less (P<.06) for pigs fed CMH than for control pigs.

These results suggest that added CMH does not affect finishing-pig growth performance but may increase longissimus muscle firmness and decrease drip loss at 14 d postmortem. That decrease may be associated with increased cellular water retention. Drip loss at 24 h was less for pigs fed maintenance and late load CMH, but pigs fed the early load CMH treatment had greater drip loss and were similar to the control group.

This variability was also evident in comparisons of the water holding capacity of the early load CMH pigs with that of pigs in other treatments. We have no explanation as to why pigs fed the early load CMH treatment were not similar to those in the other CMH treatments. Creatine has been shown to be most beneficial to human athletes actively involved in anaerobic exercise. Therefore, the lack of differences in growth performance was not surprising because pigs are relatively sedentary during late finishing.

Further research needs to be conducted to better understand the effects and mode of action of creatine on pork quality under different conditions. However, if further studies confirm pork quality benefits, such as decreased drip loss and increased muscle firmness, the potential may exist for CMH to be used in the swine industry.

Table 1. Effect of Creatine Monohydrate on Finishing Pig Growth Performance[a,b]

Days before Slaughter	Creatine g/day				
30-25	0	3	25	0	
25-5	0	3	3	0	
Item 5-0	0	3	3	25	SEM
ADG, lb	2.10	2.08	2.09	2.07	.04
ADFI, lb	7.23	7.22	7.17	7.20	.09
F/G	3.45	3.47	3.43	3.48	.05

Table 2. Carcass Characteristics of Finishing Pigs Fed Creatine Monohydrate[a]

Days before Slaughter	Creatine g/day				
30-25	0	3	25	0	
25-5	0	3	3	0	
Item 5-0	0	3	3	25	SEM
Dressing, %	73.76	73.45	72.97	73.31	.29
Shrink loss, %	.42	.44	.39	.40	.06
Cold carcass wt., lb	183.81	180.54	179.41	179.78	1.02
Backfat, in					
First rib	1.54	1.55	1.55	1.57	.03
Tenth rib	.81	.80	.86	.81	.04
Last rib	.92	.88	.86	.90	.03
Last lumbar	.70	.73	.71	.72	.04
Average	1.06	1.05	1.04	1.06	.03
Carcass length, in	32.45	32.75	32.95	32.67	.13
Loin eye area, sq in.	6.39	6.21	6.02	6.29	.12
Lean, %	52.82	52.68	51.75	52.82	.59
Organ wt, lb					
Heart weight	.88	.86	.85	.87	.02
Kidney weight	.81	.84	.77	.81	.02
Serum creatinine, mg/dL	1.90	1.83	1.86	1.89	.03

[a]Hot carcass weight was used as a covariate in the statistical analysis.

Table 3. Carcass Quality Measures of Finishing Pigs Fed Creatine Monohydrate (24 h postmortem)

Item	Days before Slaughter	Creatine g/day				SEM
	30-25	0	3	25	0	
	25-5	0	3	3	0	
	5-0	0	3	3	25	
Visual color[a]		2.81	3.00	2.84	2.94	.16
Firmness[a,b]		1.94	2.31	2.00	2.19	.09
Marbling[a]		1.59	1.78	1.66	1.47	.13
L*[c]		57.61	57.37	58.19	55.98	.71
a*[c]		10.01	9.95	10.05	9.81	.27
b*[c]		17.37	16.57	17.34	16.60	.36
a*/b*[c]		.58	.60	.59	.60	.01
Hue angle[c]		59.88	59.13	59.84	59.36	.49
Saturation index[c]		20.08	19.37	20.10	19.33	.42
%R610/%R580[c]		2.29	2.27	2.27	2.30	.03
%R630/%R580[c]		2.69	2.67	2.67	2.72	.05
Drip loss, %[d,e]		5.31	4.06	5.76	4.15	.49
Water holding capacity, %						
24 h postmortem		3.95	3.89	4.02	3.83	.15
14 d postmortem		3.58	3.39	3.38	3.39	.11
Temperature, °C						
45 m postmortem		37.76	37.78	37.98	37.49	.29
24 h postmortem		.98	.64	.83	.80	.24
pH						
45 m postmortem		6.30	6.48	6.36	6.36	.06
24 h postmortem		5.43	5.44	5.41	5.46	.02

[a]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.
[b]Control vs creatine (P<.05).
[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), or vividness or intensity (saturation index).
[d]Maintenance and late load CMH vs early load (P<.05).
[e]Control vs maintenance (P<.09).

Table 4. Carcass Quality Measures of Finishing Pigs Fed Creatine Monohydrate (14-d postmortem)

Days before Slaughter	Creatine g/day				
30-25	0	3	25	0	
25-5	0	3	3	0	
Item 5-0	0	3	3	25	SEM
Visual color	3.00	3.13	3.09	3.09	.14
Firmness[a]	2.06	2.19	2.22	2.31	.08
Marbling	1.88	1.94	1.97	1.78	.12
L*	59.76	58.90	61.01	59.49	.55
a*	10.11	10.38	9.60	10.15	.34
b*	17.57	17.76	17.62	17.66	.31
a*/b*	.57	.58	.54	.57	.01
Hue angle	60.20	59.81	61.50	60.23	.51
Saturation index	20.29	20.60	20.08	20.39	.42
%R610/%R580	2.30	2.36	2.23	2.30	.03
%R630/%R580	2.27	2.33	2.21	2.38	.07
Drip loss, %[b]	1.28	.89	.99	1.12	.12
Loin purge loss, %	3.52	3.72	3.21	3.19	.33
Chop thawing loss, %	5.77	5.52	5.55	5.68	.18
Chop cooking loss, %	25.26	25.11	25.77	25.10	.95
Chop shear force, kg	3.26	3.26	3.13	3.29	.21
Longissimus chemical composition, %					
Crude protein	22.77	23.14	22.81	22.82	.24
Moisture	73.44	73.20	73.20	73.50	.21
Lipid	2.04	2.37	2.41	2.08	.15

[a]Control vs CMH (P<.05).
[b]Control vs CMH (P<.06).

CHARACTERIZING THE FEEDING VALUE OF EXTRUDED-EXPELLED SOYBEAN MEAL WITH OR WITHOUT ADDED FAT IN A COMMERCIAL SWINE PRODUCTION FACILITY[1,2]

M. J. Webster, S. S. Dritz[3], R. D. Goodband, M. D. Tokach, J .L. Nelssen, J. C. Woodworth, M. De La Llatta, and N. Said

Summary

A total of 1,200 gilts was used to evaluate the effects of replacing conventionally processed soybean meal with extruded-expelled soybean meal on finishing pig growth performance. Dietary treatments were arranged in a 2 × 3 factorial with two sources of soybean meal (solvent-extracted or extruded-expelled) and three levels of added fat (none, 3.4, and 7% in Phase 1 than decreasing in subsequent phases). Energy levels were adjusted such that the higher energy in extruded-expelled soybean meal (with or without added fat) was equal to that provided by solvent-extracted soybean meal with added fat. From 54 to 135 lb, pigs fed extruded-expelled soybean meal had improved ADG and F/G compared to those fed solvent-extracted soybean meal. Increasing added fat in either extruded-expelled- or solvent-extracted soybean meal-based diets linearly improved ADG and F/G. From 135 to 270 lb, pigs fed extruded-expelled soybean meal and(or) increasing added fat had decreased feed intake. For the overall growing-finishing period, ADG was unaffected by increasing energy density. However, ADFI was decreased and F/G improved as energy density of the diet was increased either with extruded-expelled soybean meal and(or) added fat. Carcass leanness was not affected by dietary treatment. These results indicate that increasing the energy density of the diet by using extruded-expelled soybean meal and(or) added fat improves feed efficiency in finishing pigs reared in a commercial environment.

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

Introduction

The ileal amino acid digestibility and metabolizable energy (ME) of extruded-expelled soybean meal were established in a previous KSU study. As expected because of the higher fat content, the extruded-expelled soybean meal had a higher ME content compared to conventional soybean meal.

Recent research at KSU indicated a linear improvement in feed efficiency through the growing and finishing phases with increasing additions of fat (0 to 6% choice white grease) in diets. However, the improvements in ADG were not the same throughout the finishing phase. During the growing phase (80 to 130 lb) when the pigs were in an energy dependant phase of growth, increasing added dietary fat linearly increased growth rate. Each 1% added fat improved ADG approximately 2%. During the late finishing phase (210 to 260 lb), added fat had no effect on ADG, but F/G continued to be improved. Thus, the economic value of added dietary fat for improv-

[1]The authors wish to thank Insta-Pro International, a division of Triple "F", Des Moines, IA, for providing the extruded-expelled soybean meal used in this study.

[2]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.

[3]Food Animal Health and Management Center.

ing ADG is greater during the growing phase.

The linear improvements suggest that when economical, the highest level of added dietary fat should be fed. Added dietary fat levels in corn-soybean meal based diets usually are limited to 6% for feed manufacturing and handling reasons. Thus, extruded-expelled soybean meal may provide an increase in energy density above that of a diet with 6% added fat. In addition, use of extruded-expelled soybean meal can result in higher energy density for diets during the growing phase, when the value of the energy density is greater for ADG improvements.

Therefore, the main objective of this study was to verify the feeding value of extruded-expelled soybean meal in a growth trial conducted under commercial conditions. A second objective was to determine if extruded-expelled soybean meal can provide added dietary energy in addition to maximum levels of added dietary fat.

Procedures

A total of 1,200 gilts (PIC C22 × 337), initially 54 lb, was housed in a commercial research facility in southwestern Minnesota. The barn was a 48-pen curtain-sided, total-slatted finishing barn with 7.2 sq ft provided per pig and each pen initially stocked with 25 pigs. Eight pens per treatment were arranged in a 2 × 3 factorial with two soybean sources and three levels of increasing energy density as the main effects. The control diet was corn and solvent-extracted soybean meal-based and contained no added fat. In the next dietary treatment, the solvent-extracted soybean meal was replaced by extruded-expelled soybean meal. We then added fat (3.4 to 1.5% based on phase) to the solvent-extracted soybean meal-based diet to equal the energy content of the extruded-expelled soybean meal diet. This amount of added fat then was added to the extruded-expelled-soybean meal-based diet, and a solvent-extracted soybean meal diet with added fat (7 to 3.1%) was formulated to equal the energy content of the extruded-expelled soybean meal diet with added fat. The last dietary treatment consisted of extruded-expelled soybean meal with 7 to 3.1% added fat, the same amount added to the solvent-extracted soybean meal diet. So, the diet containing solvent-extracted soybean meal with the medium level of added fat was formulated to equal the ME level of the extruded-expelled soybean meal diet with no added fat. In addition, the diet containing solvent-extracted soybean meal with the high level of added fat was formulated to equal the ME level of the extruded-expelled soybean meal diet with the medium levels of fat.

All pigs were phase-fed four diets from 54 to 270 lb (Tables 1 through 4). Diets were formulated to the same digestible lysine to energy ratio within each phase. Because the lysine content of each diet was decreased as the pigs became heavier, the amount of extruded-expelled soybean meal was decreased. This decreased the amount of extra ME it provided relative to diets containing solvent-extracted soybean meal. Therefore, the amount of added fat to equalize energy density between solvent-extracted and extruded-expelled soybean meals decreased in each successive phase. Each phase was fed for approximately 28 d. All diets were formulated using NRC (1998) nutrient values for solvent-extracted soybean meal. Metabolizable energy and digestible amino acid values estimated in a previous KSU study were used for the extruded-expelled soybean meal.

Pigs were weighed and feed disappearance was determined every 14 days. The ADG, ADFI, and F/G were determined for the performance data. At market time, pigs were tattooed by pen for treatment identification and sent to Swift in Worthington, MN, where carcass characteristics (loin depth, fat depth, hot carcass weight, dressing percentage, lean yield, and fat-free lean index, FFLI) were measured.

Results and Discussion

From d 0 to 54, (54 to 135 lb), a source × fat interaction ($P<.05$) was observed for ADG (Table 5). In the diets without added fat, pigs fed solvent-extracted soybean meal

had greater ADG than those fed extruded-expelled soybean meal. However, when medium and high levels of fat were added, pigs fed extruded-expelled soybean meal had greater ADG than those fed solvent-extracted soybean meal. Replacing solvent-extracted soybean meal with extruded-expelled soybean meal had no effect on ADFI but tended (P<.06) to improve feed efficiency. Increasing added fat decreased (linear, P<.03) ADFI and F/G.

From d 54 to 126, ADG was not affected (P>.12) by either extruded-expelled soybean meal or added fat. However, ADFI decreased with the addition of extruded-expelled soybean meal (P<.02) or increasing added fat (linear, P<.01). Feed efficiency was not affected (P>.18) by dietary treatment.

For the overall experiment, ADG was not affected (P>.32) by either extruded-expelled soybean meal or added fat. However, increasing the dietary energy content by either replacing solvent-extracted soybean meal with extruded-expelled soybean meal and(or) increasing added fat decreased ADFI (P<.06, and linear, P<.03, respectively) and improved F/G (P<.02, and linear P<.01, respectively). No differences were observed in the carcass data among the dietary treatments.

The results of this experiment agree with previous research evaluating increasing dietary energy density in pigs reared in commercial environments. Growing pigs are in an energy-dependent stage. Therefore, increasing energy density of the diet either by using extruded-expelled soybean meal and(or) adding fat increases ADG and improves F/G. In late finishing, when the pig's energy intake begins to exceed that necessary for maximum protein deposition, increasing dietary energy density does not affect ADG, but can reduce ADFI and improve F/G.

Furthermore, results indicate that extruded-expelled soybean meal and solvent-extracted soybean meal affect ADG, ADFI, and F/G similarly when formulated to the same energy level. When more than 6% fat is added, feed manufacturing and handling characteristics become problems. Therefore, higher energy levels could be obtained by using extruded-expelled soybean meal with 6% added fat.

Table 1. Diet Compositions during Phase 1 (60 to 90 lb)

	Fat Level:	None		Medium		High	
	Source:	SMB[1]	EE Soy[2]	SBM	EE Soy	SBM	EE Soy
Ingredients, %	ME Level:	1,503	1,571	1,571	1,643	1,643	1,721
Corn		69.22	69.99	63.59	64.59	57.77	58.78
Soybean meal, 46.5%		28.05	0.00	30.16	0.00	32.30	0.00
EE soy w/o hulls		0.00	26.92	0.00	28.85	0.00	30.94
Choice white grease		0.00	0.00	3.40	3.40	7.00	7.00
Monocalcium P, 21% P		1.05	1.33	1.10	1.39	1.16	1.48
Limestone		1.00	1.00	1.00	1.00	1.00	1.00
Salt		0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix		0.08	0.08	0.08	0.08	0.08	0.08
Trace mineral premix		0.15	0.15	0.15	0.15	0.15	0.15
Lysine HCl		0.15	0.15	0.15	0.15	0.15	0.15
DL-methionine		0.00	0.03	0.02	0.04	0.04	0.07
Total		100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis							
Apparent digestible lysine, %		0.96	1.00	1.00	1.05	1.05	1.10
Protein, %		18.90	19.50	19.40	20.10	19.90	20.60
ME, kcal/lb		1503	1571	1571	1643	1643	1721
Dig. lysine:cal ratio, g/mcal		2.89	2.89	2.89	2.89	2.89	2.89
Calcium, %		0.69	0.74	0.71	0.75	0.72	0.78
Phosphorus, %		0.61	0.66	0.62	0.67	0.63	0.69
Available phosphorus, %		0.29	0.31	0.30	0.32	0.32	0.33

Table 2. Diet Compositions during Phase 2 (90 to 135 lb)

	Energy Level:	None		Medium		High	
	Source:	SMB[1]	EE Soy[2]	SBM	EE Soy	SBM	EE Soy
Ingredients, %	ME Level:	1,506	1,565	1,565	1,628	1,628	1,694
Corn		72.48	73.79	67.98	69.40	63.14	64.81
Soybean meal, 46.5%		24.89	0.00	26.49	0.00	28.23	0.00
EE soy w/o hulls		0.00	23.35	0.00	24.83	0.00	26.28
Choice white grease		0.00	0.00	2.90	2.90	6.00	6.00
Monocalcium P, 21% P		1.00	1.18	1.00	1.23	1.00	1.25
Limestone		0.90	0.95	0.90	0.90	0.90	0.90
Salt		0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix		0.08	0.08	0.08	0.08	0.08	0.08
Trace mineral premix		0.15	0.15	0.15	0.15	0.15	0.15
Lysine HCl		0.15	0.15	0.15	0.15	0.15	0.15
DL-methionine		0.00	0.00	0.00	0.01	0.00	0.03
Total		100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis							
Apparent digestible lysine, %		0.88	0.91	0.91	0.94	0.95	0.97
Protein, %		17.70	18.10	18.10	18.40	18.50	18.80
ME, kcal/lb		1506	1565	1565	1628	1628	1694
Dig. lysine:cal ratio, g/mcal		2.65	2.63	2.65	2.62	2.65	2.61
Calcium, %		0.63	0.68	0.64	0.67	0.64	0.68
Phosphorus, %		0.58	0.61	0.58	0.62	0.58	0.63
Available phosphorus, %		0.28	0.28	0.28	0.28	0.28	0.29

[1]SBM = solvent-extracted soybean meal, 46.5% crude protein.
[2]EE Soy = extruded-expelled soybean meal without hulls.

Table 3. Diet Compositions during Phase 3 (135 to 190 lb)

Energy Level:	None		Medium		High	
Source:	SMB[1]	EE Soy[2]	SBM	EE Soy	SBM	EE Soy
Ingredients, % ME Level:	1,512	1,553	1,553	1,596	1,596	1,641
Corn	80.54	81.64	77.67	78.88	74.72	76.01
Soybean meal, 46.5%	17.15	0.00	18.02	0.00	18.93	0.00
EE soy w/o hulls	0.00	15.92	0.00	16.66	0.00	17.43
Choice white grease	0.00	0.00	2.00	2.00	4.10	4.10
Monocalcium P, 21% P	0.75	0.88	0.75	0.90	0.75	0.90
Limestone	0.90	0.90	0.90	0.90	0.90	0.90
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.06	0.06	0.06	0.06	0.06	0.06
Trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10
Lysine HCl	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis						
Apparent digestible lysine, %	0.70	0.71	0.71	0.73	0.73	0.74
Protein, %	14.80	15.00	15.00	15.10	15.10	15.30
ME, kcal/lb	1512	1553	1553	1596	1596	1641
Dig. lysine:cal ratio, g/mcal	2.09	2.07	2.08	2.06	2.08	2.06
Calcium, %	0.56	0.58	0.57	0.59	0.57	0.59
Phosphorus, %	0.50	0.52	0.50	0.52	0.50	0.52
Available phosphorus, %	0.22	0.22	0.22	0.22	0.22	0.22

Table 4. Diet Compositions during Phase 4 (190 to 260 lb)

Energy Level:	None		Medium		High	
Source:	SMB[1]	EE Soy[2]	SBM	EE Soy	SBM	EE Soy
Ingredients, % ME Level:	1,515	1,546	1,545	1,578	1,578	1,611
Corn	84.82	85.68	82.76	83.79	80.62	81.66
Soybean meal, 46.5%	12.97	0.00	13.53	0.00	14.07	0.00
EE soy w/o hulls	0.00	11.97	0.00	12.42	0.00	12.93
Choice white grease	0.00	0.00	1.50	1.50	3.10	3.10
Monocalcium P, 21% P	0.70	0.78	0.70	0.78	0.70	0.80
Limestone	0.85	0.85	0.85	0.85	0.85	0.85
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.06	0.06	0.06	0.06	0.06	0.06
Trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10
Lysine HCl	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis						
Apparent digestible lysine, %	0.60	0.60	0.61	0.61	0.62	0.62
Protein, %	13.20	13.30	13.30	13.40	13.40	13.50
ME, kcal/lb	1,515	1,546	1,545	1,578	1,578	1,611
Dig. lysine:cal ratio, g/mcal	1.79	1.77	1.78	1.76	1.77	1.76
Calcium, %	0.52	0.53	0.52	0.53	0.52	0.54
Phosphorus, %	0.47	0.49	0.47	0.48	0.47	0.49
Available phosphorus, %	0.20	0.20	0.20	0.20	0.20	0.20

[1]SBM = solvent-extracted soybean meal, 46.5% crude protein.

[2]EE Soy = extruded-expelled soybean meal without hulls.

Table 5. Characterizing the Feeding Value of Express Soy in a Commercial Swine Production Facility[1]

	Treatments													
Fat Level:	None		Medium		High						Fat		ME	
Source:	SBM[2]	EE Soy[3]	SBM	EE Soy	SBM	EE Soy								
Item ME Level:	1,509	1,559	1,559	1,611	1,611	1,667	SEM	Source	Fat	Source×Fat	Linear	Quad	Linear	Quad
Phase 1 & 2 (d 0 to 54)														
ADG	1.56	1.53	1.56	1.68	1.63	1.67	.026	.06	.001	.02	.0003	.23	.001	.63
ADFI	3.38	3.29	3.24	3.33	3.23	3.18	.059	.75	.10	.26	.03	.81	.03	.80
F/G	2.17	2.15	2.07	1.98	1.97	1.91	.038	.07	.0001	.60	.0001	.44	.0001	.91
Phase 3 & 4 (d 54 to 126)														
ADG	1.71	1.71	1.72	1.61	1.66	1.66	.032	.18	.25	.14	.12	.53	.11	.81
ADFI	5.30	5.05	5.20	4.82	4.88	4.92	.100	.03	.04	.11	.01	.74	.004	.17
F/G	3.10	2.95	3.02	3.00	2.94	2.97	.052	.28	.37	.25	.18	.71	.09	.22
Overall (d 0 to 126)														
ADG	1.64	1.63	1.65	1.64	1.65	1.66	.020	.81	.61	.80	.32	.94	.46	.66
ADFI	4.45	4.28	4.33	4.18	4.16	4.15	.070	.05	.02	.44	.01	.91	.002	.28
F/G	2.71	2.62	2.62	2.55	2.52	2.50	.031	.02	.0001	.52	.0001	.91	.0001	.32
Final wt.	270	269	272	266	271	273	2.70	.55	.47	.31	.36	.42	.50	.40
Packing Plant Data w/o HCW Covariate														
Live wt.	270	268	273	267	271	275	2.64	.48	.25	.21	.13	.54	.28	.27
HCW	205	202	208	201	206	208	1.85	.13	.15	.09	.07	.47	.38	.16
Yield, %	75.9	75.5	76.0	75.6	76.0	75.6	.003	.14	.95	.99	.77	.87	.56	.99
Back fat, in.	.665	.675	.700	.663	.683	.699	.015	.75	.36	.14	.15	.94	.19	.91
Loin depth, in.	2.36	2.26	2.30	2.28	2.25	2.31	.036	.52	.70	.15	.42	.78	.31	.07
Lean, %	55.8	55.3	55.0	55.5	55.1	55.1	.254	.98	.25	.20	.10	.87	.10	.49
FFLI	50.6	50.4	50.2	50.5	50.4	50.2	.162	.75	.60	.37	.34	.71	.23	.60
Packing Plant Data w/ HCW Covariate														
Yield, %	75.9	75.5	76.0	75.6	76.0	75.6	.003	.17	.96	.99	.83	.86	.48	.85
Back fat, in.	.665	.686	.693	.677	.681	.689	.014	.71	.73	.38	.51	.67	.32	.51
Loin depth, in.	2.36	2.30	2.27	2.32	2.25	2.27	.031	.82	.14	.20	.05	.89	.11	.21
Lean, %	55.8	55.3	55.1	55.4	55.2	55.1	.263	.78	.41	.27	.20	.78	.15	.31
FFLI	50.6	50.3	50.3	50.4	50.4	50.3	.169	.66	.69	.45	.46	.67	.28	.49

[1]A total of 1,200 PIC gilts with an average initial wt. of 54 lb were used in the experiment. The values represent the mean of eight pens per treatment and 25 pigs per pen. [2]SBM = solvent-extracted soybean meal. [3]EE Soy = extruder-expelled soybean meal without hulls.

VARIATION IN THE DIGESTIILITY OF AMINO ACIDS IN SOYBEAN MEAL FROM A SINGLE PROCESSING PLANT[1,2]

D. J. Lee, J. D. Hancock, J. M. DeRouchey, C. A. Maloney, D. W. Dean, and H. Cao

Summary

Digestibilities of amino acids among samples of soybean meal (SBM) collected during a fall harvest season (4 collections made 15 d apart) were similar, except that true digestibility from tryptophan was lower for a sample collected on d 30 of the experiment vs SMB samples collected on the other dates. Our data suggest that proximate components and amino acid digestibilities of the SBM were very consistent and uniform during the 45 d of sample collection in one processing plant.

(Key Words: Soybean Meal, Digestibility, Amino Acids.)

Introduction

Soybean meal (SBM) is the most commonly used protein source in diets for pigs because of its high protein content and low cost. However, concern still exists about variability in protein content and quality that might result from inconsistencies in processing conditions at soybean crushing plants. To inactivate antinutritional factors, heat is applied during production of SBM. However, if too much heat is applied, nutrient availability can be compromised. This perceived variability in content and quality of protein is of concern to soybean processors because of other high quality amino acid sources (e.g., fishmeal, canola meal, and miscellaneous animal protein sources) that compete with SBM produced in the United States. Thus, an experiment was designed with the objectives: 1) to gain an understanding of the variation encountered in the nutrient content of SBM processed within a single plant over several weeks and 2) to determine the apparent and true amino acid digestibilities in these same SBM samples.

Procedures

Four samples (181 kg each) of soybean meal (SBM) were acquired 15 days apart (d 0, 15, 30 and 45) from a soybean processing plant in northeast Kansas (Bunge Corp. Soybean Processing, Emporia, KS) during a fall harvest season. These SBM samples were compared to an SBM control that originated from the fall harvest in Ohio and a soy protein concentrate (Central Soya, in Decater, IN). Casein (Carl Ackey, Lewisburg, OH) was used to formulate a low protein diet to allow estimation of endogenous losses and to allow calculation of true digestibility of amino acids. All diets (except the casein-based formulation) were cornstarch-based and formulated to 17% CP, (4.44% CP for the casein diet), .9% Ca, and .75% P (Table 1). Vitamins and minerals were added to meet or exceed NRC (1998) recommendations.

Nine barrows (55 lb initial BW) were fitted surgically with a simple T-cannula

[1]This study was done in collaboration with North Carolina State University; University of Illinois; The Ohio State University; and Wageningen Agriculture University, the Netherlands.

[2]Appreciation is extended to the Illinois Soybean Program Operating Board (ISPOB) for financial assistance.

approximately 6 inches anterior to the ileocecal valve. Following surgery, pigs were housed in steel metabolism crates (4.9 ft × .1.6 ft) in a temperature-controlled (72°F) room during a 10-d recovery period. At the end of the recovery period, the pigs were weighed and assigned randomly to treatments in a 7 × 7 Latin square design (pig and period as blocking criteria).

Feed was provided at 7:00 a.m. and 7:00 p.m. each day using the equation: daily feed allowance = $BW^{.75}$ × .09. Chromic oxide (.5%) was added as an indigestible marker to allow determination of apparent digestibility coefficients. The pigs were allowed 5 d for adjustment to diet followed by 2 d of digesta collection (from 7:00 a.m. to 7:00 p.m.). Collections of digesta were made every 20 to 30 min, emptied into a plastic container, and frozen. Upon completion of the collection period, the samples were thawed and homogenized, and subsamples were re-frozen until they could be lyophilized and ground for laboratory analyses.

Amino acid analyses were performed on the ileal collection for each pig along with the soy samples and diets. Diet and ileal samples were analyzed for dry matter, chromium, ash, crude protein, fat, fiber, and amino acid concentrations. Color of the SBM samples was characterized using Hunter Lab (L*, a*, b*) to give indications of surface lightness, redness, and yellowness, respectively. The soy products also were analyzed for urease activity, protein solubility in a KOH solution, and protein dispersibility in water.

Data from the digestibility experiment were analyzed as a Latin square design using the GLM procedure of SAS. The statistical model included the effects of pig, period, and treatment (protein source). Means were separated using the LSD procedure.

Results and Discussion

Dry matter concentrations for the protein sources (Table 2) were very similar (ranging from 88.5 to 90.2%). Likewise, other proximate components (i.e., N, ether extract, crude fiber, ash, and nitrogen free extract) and amino acid concentrations were typical for the protein sources and similar among the SBM samples. However, chemical analyses are not good indicators of differences in nutrient digestibility that can result from variation in processing (e.g., over- or underheating). Instead, soybean processors prefer a urease index between .02 and .2)pH to indicate adequate thermal treatment. For our experiment, urease indexes ranged from .01 to .03)pH, suggesting that heat treatment was adequate to inactivate the protease inhibitors found in raw soybeans.

Another assay that can be used to detect over/underprocessing is color determination using the Hunter miniscan. Our SBM samples had Hunter L* values ranging from 61.5 to 71.8, a* values from 4.7 to 5.9, and b* values from 31.2 to 38.4. The control SBM (from Ohio) had a Hunter L* value of 71.1, a* value of 5.0, and b* value of 31.9. Thus, all of the SBM samples used in our experiment were similar in color, suggesting similar processing conditions.

Endogenous losses of amino acids (Table 3) were determined by feeding pigs a casein-based diet. This allowed calculation of true digestibility of amino acids. For example endogenous lysine losses ranged from .44 to .58 and averaged .51%. The underlying assumption in calculating true digestibility using this procedure is that the protein within the casein was 100% digestible.

For digestibility of nutrients, the soy protein concentrate had lower apparent and true digestibility coefficients for several of the amino acids compared to the SBM treatments (Table 4). This response is difficult to explain, because most known antinutritional factors (e.g., lectins, protease inhibitors, oligosaccharides, and antigenic constituents) in soy protein concentrates supposedly are either removed or inactivated by a hot alcohol wash before toasting or extruding.

As for the SBM treatments, apparent digestibility of DM was greater for the SBM control and the sample collected on d 15 vs the samples collected on d 0 and 45 ($P<.05$).

Apparent digestibility of N was similar among the various SBM samples (P>.05) but the SBM control did have greater apparent digestibility of Ile and greater true digestibilities of Ile, Leu, and Val than the SBM collected on d 0 (P<.05). Also, the SBM control had greater apparent digestibilities of Ile and Thr and greater true digestibilities of His, Ile, Trp, and Val than the SBM collected on d 30 (P<.05). Among the SBM samples collected on d 0, 15, 30, and 45, only one response criterion (true digestibility of Trp for d 0 vs d 30) was different, with values being similar to those reported by the NRC for SBM (47.5% CP). Thus, the differences in digestibilities of nutrients and amino acids for the SBM samples collected on different dates were inconsistent and small in magnitude.

In conclusion, our results indicate that day of processing at a single crushing plant probably is not a major source of variability in the nutritional value of soybean meal. However, several differences in the apparent and true digestibilities of amino acids did occur among the soybean meal control (from Ohio), the soy protein concentrate, and the soybean meal samples that we collected in Kansas. Those differences suggest that variation (sometimes considerable) in soy products does exist.

Eldo Heller, Breeding Barn Manager.

Table 1. Compositions of Diets

			Soybean Meals[a]				
Item, %	Soy Concentrate	SBM Control	d 0	d 15	d 30	d 45	Casein
Corn starch	46.00	38.10	37.28	37.54	38.31	37.14	61.60
Sucrose	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Soybean meal	—	35.25	36.07	35.81	35.04	36.21	—
Soy protein concentrate	27.00	—	—	—	—	—	—
Casein	—	—	—	—	—	—	5.00
Cellulose fiber	—	—	—	—	—	—	5.00
Corn oil	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Salt	.35	.35	.35	.35	.35	.35	.40
Dicalcium phosphate	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Limestone	.45	.45	.45	.45	.45	.45	.60
Vitamins and minerals	.35	.35	.35	.35	.35	.35	.35
Chromic oxide	.50	.50	.50	.50	.50	.50	.50
Potassium carbonate (55% K)	.35	—	—	—	—	—	1.40
Magnesium oxide (58% Mg)	¾	—	—	—	—	—	.15
Calculated Analysis							
CP	17.00	17.00	17.00	17.00	17.00	17.00	4.44
Lysine	1.03	1.05	1.05	1.05	1.05	1.05	.37
Ca	.90	.90	.90	.90	.90	.90	.90
P (total)	.75	.75	.75	.75	.75	.75	.61
Analyzed Values							
CP	16.99	16.29	17.94	17.41	17.42	16.11	5.51
Lysine	1.04	1.07	1.19	1.29	1.04	1.07	.38

[a]Soybean meals were acquired from Bunge Corp. Soybean Processing of Emporia, KS.

Table 2. Chemical Analyses of Protein Sources, %

Item	Soy Conc.	SBM Control	Soybean Meals[a] d 0	d 15	d 30	d 45	Casein
Proximate Components[b]							
DM, %	90.2	90.0	88.8	88.7	88.6	88.5	89.9
N, %	68.1	54.4	56.3	56.3	56.3	56.3	98.1
Ether extract, %	.6	2.5	2.0	1.9	1.7	1.9	.2
Crude fiber, %	3.9	3.4	3.9	3.6	3.7	3.6	.1
Ash, %	7.8	7.2	8.2	8.1	8.3	8.3	3.9
Nitrogen free extract, %	9.9	22.9	18.5	19.0	18.7	18.5	0
Urease index, ΔpH	.03	.03	.03	.01	.03	.03	—
Trypsin inhibitor, mg/g	.50	.48	.51	.55	.57	.62	—
Hunter L*	67.2	71.1	61.5	70.8	71.4	71.8	53.8
a*	4.7	5.0	5.9	4.9	4.7	5.0	6.6
b*	36.6	31.9	38.4	32.3	32.1	31.2	38.7
Protein solubility index, %	54.1	79.5	79.7	77.8	79.7	80.7	96.3
Protein dispersability index, %	4.1	28.0	26.4	27.7	33.4	33.8	—
Indispensable amino acid, %							
Arginine	4.68	3.58	3.53	3.59	3.58	3.57	3.03
Histidine	1.74	1.30	1.40	1.37	1.35	1.34	2.43
Isoleucine	2.94	2.17	2..10	2.16	2.22	2.17	4.00
Leucine	4.97	3.69	3.73	3.78	3.79	3.76	7.68
Lysine	4.08	2.99	3.07	3.12	3.13	3.11	6.39
Methionine	.81	.66	.71	.71	.74	.73	2.35
Phenylalanine	3.24	2.44	2.60	2.58	2.55	2.54	4.31
Threonine	2.55	1.87	1.85	1.84	1.85	2.84	3.52
Tryptophan	.83	.61	.79	.74	.76	.77	1.17
Valine	3.15	2.34	2.17	2.25	2.33	2.29	5.24
Total	28.99	21.65	21.95	22.14	22.30	22.12	40.12
Dispensable amino acids, %	30.52	22.66	22.69	23.13	23.34	23.22	42.51

[a]Soybean meals were acquired from Bungee Corp. Soybean Processing, Emporia, KS.
[b]Dry matter basis.

Table 3. Endogenous Losses of Amino Acids in Pigs, g/d[ab]

	Indispensable Amino Acids									
Period	Arginine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Threonine	Tryptophan	Valine
1	.52	.24	.50	.72	.58	.12	.41	.62	.14	.59
2	.72	.20	.42	.62	.44	.11	.35	.63	.13	.52
3	.50	.24	.60	.77	.59	.17	.40	.74	.17	.65
4	1.14	.24	.65	.74	.50	.17	.36	.87	.18	.67
5	.54	.23	.60	.77	.49	.15	.38	.74	.10	.58
6	.56	.29	.84	.92	.52	.17	.46	.92	.19	.84
7	.91	.26	.59	.79	.51	.13	.40	.78	.13	.64
Mean	.70	.24	.60	.76	.52	.15	.39	.76	.15	.64

[a]Values were obtained by feeding a purified diet with 5% added casein.
[b]Values are reported on a dry matter basis.

Table 4. Apparent and True Digestibilities of Amino Acids in Soybean Protein Meals[a]

				Soybean Meals[b]				
Item	SBM 47.5%[c]	Soy Conc.	SBM Control	d 0	d 15	d 30	d 45	SE
DM digestibility	—	80.6^{xy}	81.6^{x}	79.4^{y}	81.6^{x}	79.8^{xy}	79.2^{y}	.6
N digestibility	—	76.3^{y}	82.1^{x}	79.3^{xy}	82.1^{x}	79.8^{xy}	81.1^{x}	1.3
Arg digestibility, %								
Apparent	90.0	89.8	92.1	91.0	91.9	91.0	91.5	1.7
True	94.0	93.8^{y}	96.1^{x}	95.0^{xy}	95.8^{x}	95.0^{xy}	95.4^{xy}	.6
His digestibility, %								
Apparent	86.0	83.8^{z}	88.7^{x}	87.8^{x}	88.5^{x}	86.6^{xy}	87.4^{xy}	.8
True	91.0	87.6^{z}	92.5^{x}	91.3^{xy}	92.0^{xy}	90.2^{y}	91.0^{xy}	.8
Ile digestibility, %								
Apparent	84.0	83.6^{y}	86.6^{x}	84.1^{y}	85.8^{xy}	84.3^{y}	84.9^{xy}	.8
True	89.0	89.1^{z}	92.3^{x}	89.9^{yz}	91.4^{xy}	90.0^{yz}	90.4^{xyz}	.8
Leu digestibility, %								
Apparent	84.0	81.9^{z}	85.0^{xy}	83.0^{yz}	85.0^{xy}	83.2^{yz}	83.7^{xyz}	.8
True	89.0	86.0^{z}	89.3^{x}	87.0^{yz}	89.1^{xy}	87.4^{xyz}	87.8^{xyz}	.8
Lys digestibility, %								
Apparent	85.0	82.9^{z}	87.1^{xy}	84.9^{yz}	86.7^{xy}	85.4^{xyz}	86.7^{xy}	1.1
True	90.0	86.3^{y}	90.7^{x}	88.3^{xy}	90.1^{x}	88.9^{xy}	90.0^{x}	1.1
Met digestibility, %								
Apparent	86.0	83.4^{y}	87.0^{x}	86.9^{x}	88.9^{x}	87.3^{x}	87.4^{x}	.7
True	91.0	87.8^{y}	91.8^{x}	91.2^{x}	93.2^{x}	91.4^{x}	91.5^{x}	.8
Phe digestibility, %								
Apparent	84.0	84.9	87.1	86.3	87.4	85.5	86.1	.7
True	89.0	88.1^{y}	90.4^{x}	89.3^{xy}	90.5^{x}	88.7^{xy}	89.2^{xy}	.7
Thr digestibility, %								
Apparent	78.0	74.1^{z}	78.8^{x}	76.0^{xyz}	78.0^{xy}	75.8^{yz}	75.7^{yz}	1.0
True	87.0	82.2^{z}	87.2^{x}	84.3^{xyz}	86.4^{xy}	84.3^{xyz}	84.0^{yz}	1.1
Trp digestibility, %								
Apparent	81.0	80.8^{z}	84.9^{y}	86.5^{xy}	87.9^{x}	84.3^{y}	86.5^{xy}	1.0
True	90.0	85.6^{z}	89.9^{xy}	90.3^{xy}	92.0^{x}	88.4^{yz}	90.3^{xy}	1.1
Val digestibility, %								
Apparent	81.0	80.5	85.2	82.0	83.8	82.1	82.9	1.0
True	88.0	85.9^{z}	90.8^{x}	87.9^{yz}	89.5^{xy}	87.8^{yz}	88.4^{xyz}	1.0
Total indispensable amino acid digestibility, %								
Apparent		82.7	86.3	84.8	86.4	84.5	85.4	1.6
True		87.3^{y}	91.1^{x}	89.3^{xy}	90.9^{x}	89.0^{xy}	89.7^{xy}	1.1

[a]True digestibilities were calculated using average amino acid values for pigs fed a casein-based diet. [b]Soybean meals were acquired from Bungee Corp. Soybean Processing, Emporia, KS. [c]National Research Council, 1998. [x,y,z]Means in the same row with different superscripts are different (P<.05).

EFFECTS OF REMOVING VITAMIN AND MINERAL PREMIXES ON GROWTH PERFORMANCE AND CARCASS MEASUREMENTS IN FINISHING PIGS

J. S. Park, J. D. Hancock, T. L. Gugle, C. L. Jones, C. W. Starkey, and D. J. Lee

Summary

Two hundreds sixteen pigs were used to determine the effects of deleting vitamin and mineral premixes on growth performance, carcass characteristics, and integrity of vertebrae in finishing pigs housed in large groups with extreme variation in BW. No negative effects on ADG, ADFI, F/G, carcass characteristics, or integrity of vertebrae occurred when the vitamin and mineral premix was deleted.

(Key Words: Finishing Pigs, Vitamins, Minerals.)

Introduction

Previous experiments at Kansas State University demonstrated that omitting vitamin and trace mineral premixes from diets in late finishing had no negative effects on growth performance, carcass measurements, or meat quality. However, questions have surfaced about application of this concept in situations of greater stocking densities, larger pen sizes, and less uniform weight within the pens of pigs. Thus, the objective of the experiment reported herein was to determine the effects of omitting vitamin and mineral premixes in late finishing with "commercial-type" housing and management.

Procedures

A total of 256 pigs was sorted from lightest to heaviest, and 216 were chosen and allotted to give the maximum possible body weight variation (average initial wt of 201 lb). There were 27 pigs per pen (6.8 sq ft/pig) with and four pens per treatment. Treatments were corn-soybean meal-based diets (Table 1) with and without the KSU vitamin and trace mineral premixes. The pigs were housed in a modified open-front building with 50% solid concrete and 50% concrete slat flooring. Each pen (12 ft × 16 ft) had two three-hole self-feeders and a nipple waterer to allow ad libitum consumption of feed and water.

Table 1. Basal Diets[a]

Ingredient, %	With Premixes[b]	Without Premixes[b]
Corn	79.58	79.88
Soybean meal (46.5% CP)	17.21	17.16
Soybean oil	1.00	1.00
Lysine HCL	.10	.10
Monocalcium phosphate	.52	.52
Limestone	.85	.85
Salt	.35	.35
KSU vitamin premix	.15	-
KSU trace mineral premix	.10	-
Antibiotic[c]	.12	.12
Total	100.00	100.00

[a]All diets were fed in mash form.
[b]Formulated to .80% lysine, .50% Ca, and .45% P.
[c]Supplied 100g/ton tylosin.

The pigs were slaughtered when individual pig weight reached approximately 250 lb. The pigs were shipped at 2:00 AM and killed at 7:00 AM at a commercial slaughter plant.

The heaviest half were killed at d 25 of the experiment, and the lightest half were killed on d 32 of the experiment. Last rib backfat thicknesses (measured on the midline of the split carcass) and hot carcass weights were recorded, and dressing percentage (hot carcass weight/final live weight ×100) and fat-free lean (National Pork Producers Council, 2000) were calculated. Also, broken and cracked vertebrae were counted on both sides of the split carcass.

Response criteria were ADG, ADFI, F/G, dressing percentage, last rib backfat thickness, fat-free lean, and integrity of vertebrae. All data were analyzed as a randomized complete block design, and pen was the experimental unit using the GLM procedure of SAS. Also, final variation in pigs weight within each pen was analyzed using Levene's test.

Results and Discussion

Deleting the vitamin and trace mineral premixes did not affect (P>.47)ADG, ADFI, F/G, or within-pen variation in final BW (Table. 2). Also, last rib backfat thickness, dressing percentage, fat-free lean, and broken and cracked vertebrae were not affected by the dietary treatments (P>.11).

In conclusion, removing the vitamin and mineral premixes did not affect growth performance, within-pen variability in final weight, carcass characteristics, or integrity of vertebrae in pigs fed corn-soybean-based diets from 201 to 257 lb. So, concerns about use of this feeding strategy to lower cost of gain with "commercial-type" stocking densities, pen sizes, and within-pen variation are unfounded.

Table 2. Growth Performance of Pigs Fed Diets with and without the KSU Vitamin and Mineral Premixes from 201 to 257 lb[a]

	Vitamin & Mineral Premixes			
Item	With	Without	SE	P-Value
ADG, lb	1.79	1.80	.04	.47
ADFI, lb	6.26	6.16	.10	.77
Feed/gain	3.50	3.42	.09	.51
Residual start wt[b]	8.88	9.62	.47	.31
Residual ending wt[b]	12.62	12.58	.55	.96
Backfat thickness, in	.94	.92	.01	.11
Dressing percentage	73.9	73.8	.2	.72
Fat-free lean, %	52.1	52.3	.1	.27
Pig with a broken vertebrae / pen	6.00	7.50	1.2	.39
Pig with a cracked vertebrae / pen	8.75	8.50	1.4	.90
Broken vertebrae[c] / pen	23.3	19.0	3.7	.45
Cracked vertebrae[c] / pen	12.3	9.8	1.6	.32

[a]A total of 216 pigs was used (27 pigs/pen, four pens/trt).
[b]Levene's test (absolute value of the differences between the pigs' wt and the pen mean body wt).
[c]Value represent the total number of broken(cracked) vertebrae recorded from the 54 sides of pork from each pen.

EFFECTS OF VITAMINS AND MINERAL PROTEINATES ON GROWTH PERFORMANCE AND PORK QUALITY IN FINISHING PIGS

J. S. Park, J. D. Hancock, D. H. Kropf, K. A. Hachmeister, R. H. Hines, C. L. Jones, D. W. Dean, and D. J. Lee

Summary

From 185 to 225 lb BW, no differences in ADG, ADFI, or F/G occurred among pigs fed diets without or with vitamin and trace mineral premixes. Then, from 225 to 266 lb BW, a special premix with megadoses of vitamin E, vitamin C, Mg-proteinate, and Fe-proteinate was added to the diets of half the pigs given the previous treatments. Growth performance was not different among pigs fed diets without vitamin or with the KSU and special vitamin and mineral premixes. Also, meat quality (color, marbling, and firmness scores; drip, thawing, and cooking losses; shear force; and Hunter L*a*b*) was not affected by inclusion of the KSU and special vitamin and mineral premixes.

(Key Words: Vitamins, Minerals, Pork Quality.)

Introduction

Pork quality is of increasing concern in the swine industry. Increasing incidence of PSE (pale, soft, and exudative) pork has a major impact an pork quality and the ability of U.S. pork to make inroads into the export market. Many researchers have tried to improve pork quality with nutrient modifications, such as megadosing of vitamins and use of mineral chelates and proteinates, with mixed results. Yet, in previous work done at KSU, deleting vitamin and mineral premixes in late finishing had no negative effects on pork quality. Thus, we designed an experiment to determine the effects of manipulating vitamin and mineral concentrations in diets for late finishing pigs on growth performance and pork quality.

Procedures

A total of 80 crossbred pigs (average initial BW of 185 lb) was fed corn-soybean meal-based diets (Table 1) in meal form. All nutrients met or exceed NRC (1998) requirement except for vitamins and minerals.

The pigs were blocked by weight and allotted to treatments based on ancestry. There were two pigs per pen (5 ft × 5 ft) and 10 pens per treatment in an environmentally controlled building. Each pen had a self-feeder and nipple waterer to allow ad libitum consumption of feed and water.

Treatments from an average BW of 185 lb to 225 lb were a basal diet (without the KSU vitamin and mineral premixes) and the basal diet with the KSU vitamin and mineral premixes. From 225 lb to 266 lb, treatments were: 1) a negative control diet without the KSU vitamin and mineral premixes; 2) trt 1 with a special premix (500 ppm of vitamin E, 500 ppm of vitamin C, 200 ppm of magnesium proteinate, and 150 ppm of iron proteinate); 3) a diet with the KSU vitamin and mineral premixes; and 4) trt 3 with the special premix.

The pigs were slaughtered when the average BW in the heaviest pen of a weight block reached 270 lb. Dressing percentage (hot carcass weight / final live weight × 100), last rib backfat thickness, and fat-free lean (National Pork Producers Council, 1996) were determined. Also, the front half of each loin was collected for evaluation of pork quality (color, marbling score, and firmness scores; drip, thawing, and cooking losses; shear force; and Hunter L*a*b*). The second half of each loin was vacuum packaged and

stored for 45 d at 37°F before evaluation of pork quality. This was done to "stress" pork quality and to simulate the time from slaughter in a U.S. processing plant until consumption by a consumer in Japan.

The data were analyzed as a split-plot design with whole-plot treatments of no vitamin/trace mineral premixes and standard additions of vitamin and mineral premixes from 185 to 225 lb BW. Subplot treatments (no change in vitamin/trace mineral supplementation vs addition of the special premix) were imposed within the whole-plot treatments beginning at 225 lb BW. The orthogonal contrasts used to separate treatment means were: 1) no KSU vit/min premixes vs KSU vit/min premix; 2) no special premix vs with special premix; and 3) no KSU vit/min premix vs KSU vit/min × no special premix vs special premix. Hot carcass weight was used as a covariate in analysis of data for dressing percentage, backfat thickness, and fat free lean. Pen was the experimental unit for all comparisons.

Table 1. Basal Diet[a]

Ingredient	%
Corn	79.86
Soybean meal (46.5% CP)	17.20
Soybean oil	1.00
Lysine HCl	.10
Monocalcium phosphate	.52
Limestone	.85
Salt	.35
KSU vitamin premix[b]	0 or .15
KSU trace mineral premix[b]	0 or .10
Special premix [c]	0 or .11
Antibiotic [d]	.12

[a]All diets were fed in mash form.

[b]Supplied the following per lb of complete diet: 2,999 IU of vitamin A; 449 IU of vitamin D_3; 12.0 IU of vitamin E; 1.2 mg of vitamin K (as menadione sodium bisulfite); 44.9 mg of choline; 13.5 mg of niacin; 7.8 mg of pantothenic acid (as d-calcium pantothenate); 2.2 mg of riboflavin; .009 mg of vitamin B_{12}; 49.8 mg of Zn; 74.8 mg of Fe; 5.0 mg of Cu; 12.0 mg of Mn; .1 mg of I; and .1 mg of Se.

[c]Supplied the following per lb of complete diet: 226 mg of vitamin C; 226 mg of vitamin E; 90 mg of Mg; and 68 mg of Fe.

[d]Supplied 100g/ton tylosin.

Results and Discussion

Calculated concentrations for the vitamins and minerals altered by our dietary treatments are presented in Table 2. As a percentage of NRC recommendations, the diets without added vitamin and mineral premixes were supposedly deficient in vitamin E and K, niacin, riboflavin, vitamin B_{12}, Fe, I, Se, and Zn. With addition of the KSU vitamin and mineral premixes, all of the vitamin and mineral concentrations were increased well above NRC recommendations (from 1.7 × NRC for I to 19 × NRC for Mn). Finally, the special premix resulted in 500, 46, 4.6, and 5.1 × NRC for vitamin C, vitamin E, Fe, and Mg, respectively.

From 185 to 225 lb, removing vitamin and trace mineral premixes from diets did not affect (P>.80) ADG, ADFI, and F/G of the pigs (Table 3). From 225 to 265 lb (Table 4), ADG, ADFI, and F/G again were not different (P>.15) among pigs fed diets without or with vitamin and mineral premixes. Furthermore, adding the special premix did not affect growth performance (P > .36), and no interaction resulted from combining the KSU and special premixes (P>.32).

Dressing percentage, backfat thickness, percentage carcass lean, and muscle pH at 3 h and 24 h were similar among the treatments (P>.29). Marbling and firmness score (P>.11); drip, thawing, and cooking losses (P>.24); shear force (P>.71); and Hunter L*a*b* on d 0, 2, 4, and 6 of display (P>.11) also were not affected by removing vitamin and trace mineral premixes or by adding the special premix. Indeed, the only measurement of pork quality affected by the dietary treatments was color score, for which an interaction (P>.02) occurred. Addition of the special premix decreased the color score for pigs without the KSU premixes to 225 lb and increased the color score for pigs with the KSU premixes to 225 lb. However, the response is difficult to explain and was not supported by changes (P>.11) in objective determination of color via Hunter L*a*b* (Table 5).

After 45 d of storage to stress meat quality, there still were essentially no effects of vitamin and mineral premix addition to the diets (Table 6). The one exception again was an interaction for color score (P>.02). This interaction resulted from a low mean color score when the KSU premixes were fed without the special premix and a high color score when the KSU and special premixes were fed in combination. However, this response would be difficult to explain and was not supported by change in objective measurement of color (P>.06) via Hunter L*a*b* (Table 7).

In conclusion, removing vitamin and mineral premixes had no negative effects on growth performance, carcass characteristics, or meat quality. Also, supplementation with high dosages of vitamin E (500 ppm) and vitamin C (500 ppm), 200 ppm of magnesium proteinate, and 150 ppm of iron proteinate did not improve meat quality. These data demonstrate further the lack of any negative effects in the response criteria measured in this study from deleting the KSU vitamin and mineral premixes in late finishing diets.

Table. 2 Vitamin and Mineral Concentrations in Premixes[a]

		% of NRC			
Item	NRC, unit/kg	None	KSU	Special	KSU & Special
Vit A	1,300 IU	13	523	13	523
Vit C	0	0	0	50,000	50,000
Vit D	150 IU	0	661	0	661
Vit E	11 IU	66	311	4,611	4,856
Vit K	.5 mg	29	560	29	560
Niacin	7 mg	0	534	0	534
Panthothenate	7 mg	115	389	115	389
Riboflavin	2 mg	80	372	80	372
B_{12}	5 µg	0	529	0	529
Cu	3 mg	194	562	194	562
Fe	40 mg	99	412	511	787
I	.14 mg	27	169	27	196
Mg	400 mg	400	400	450	450
Mn	2 mg	573	1,896	573	1,896
Se	.15 mg	70	202	70	202
Zn	50 mg	47	268	47	268

[a]Total basis.

Table 3. Growth Performance of Pigs Fed Diets without and with the KSU Vitamin and Mineral Premixes from 185 to 225 lb[a]

	Vitamin & Mineral Premixes			
Item	None	KSU	SE	P value
ADG, lb	2.08	2.09	.06	.95
ADFI, lb	6.21	6.26	.12	.80
F/G	2.98	3.00	.07	.96

[a]Eighty pigs were used (two pigs/pen and 20 pens/trt).

Table 4. Growth Performance of Pigs Fed Diets without and with KSU and Special Vitamin and Mineral Premixes from 225 to 265 lb[a]

	W/O KSU Premixes to 225 lb		W/ KSU Premixes to 225 lb			P-Value		
Item	W/O Special Premix	W/Special Premix	W/O Special Premix	W/Special Premix	SE	KSU	Special	KSU × Special
ADG, lb	2.38	2.46	2.30	2.21	.11	.15	.97	.45
ADFI, lb	7.23	6.93	7.01	6.98	.18	.59	.36	.50
F/G	3.12	2.89	3.09	3.19	.16	.28	.71	.32
Dressing %	72.5	73.2	72.7	72.8	.7	.88	.56	.63
Backfat thickness, in	.83	.89	.87	.87	.05	.85	.62	.57
Lean %	48.5	50.8	51.1	50.5	1.3	.41	.53	.29
pH at 3h	6.68	6.69	6.68	6.67	.04	.73	.97	.83
pH at 24h	5.90	5.89	5.90	5.92	.05	.52	.74	.50
Color score [b]	3.8	3.4	3.6	4.0	.1	.20	.85	.02
Marbling score [c]	3.0	3.1	3.1	3.7	.2	.11	.16	.28
Firmness score [d]	3.2	3.1	3.2	3.2	.2	.80	.93	.80
Drip loss, %	2.1	1.7	1.7	1.9	.4	.87	.88	.48
Thawing loss, %	1.9	2.1	2.2	1.9	.3	.87	.97	.24
Cooking loss, %	27.5	27.8	29.3	27.3	1.2	.66	.48	.37
Shear force, kg	3.70	3.71	3.79	3.57	.30	.91	.73	.71

[a]A total of 80 pigs was used (two pigs/pen, 10pens/trt).

[b]Scored on a scale of 1 = pale pinkish gray to 6 = dark purplish red (NPPC, 1999) with 3 to 4 as ideal.

[c]Scored on a scale of 1 = partially devoid to 6 = abundant (NPPC 1999) with 3 to 4 as ideal.

[d]Scored on a scale of 1= vary soft and watery to 5 = very firm and dry (1991) with 3 to 4 as ideal.

Table 5. Effects of KSU and Special Premixes on Color Stability of Pork during Display

	W/O KSU Premixes to 225 lb		W/ KSU Premixes to 225 lb			P Value		
Item	W/O Special Premix	W/Special Premix	W/O Special Premix	W/Special Premix	SE	KSU	Special	KSU × Special
Day of display								
0								
L* [a]	52.7	54.6	54.8	55.1	.8	.17	.17	.34
a*	18.7	18.6	18.4	19.1	.3	.81	.40	.17
b*	14.3	14.2	14.5	15.5	.3	.11	.18	.11
2								
L*	55.4	56.6	56.5	56.9	.8	.29	.33	.59
a*	18.1	17.9	17.9	17.9	.3	.74	.70	.70
b*	16.7	16.8	19.9	17.1	.3	.49	.62	.86
4								
L*	55.5	56.4	56.6	56.8	.7	.27	.49	.67
a*	16.7	16.4	16.4	16.5	.3	.48	.71	.45
b*	16.6	16.7	16.9	17.1	.2	.24	.55	.87
6								
L*	56.1	57.0	57.0	57.4	.8	.39	.45	.70
a*	15.4	14.8	14.7	15.0	.4	.33	.78	.35
b*	16.0	16.0	16.0	16.7	.3	.16	.36	.26

[a]Hunter 'L' values (lightness) with an acceptable range of 50 to 55, which is considered equal to color score of 2 to 3.

Table 6. Effects of KSU and Special Premixes on Visual Color and Cooking Characteristics of Pork after 45 Days of Storage

	W/O KSU Premixes to 225 lb		W/ KSU Premixes to 225 lb			P-Value		
Item	W/O Special Premix	W/Special Premix	W/O Special Premix	W/Special Premix	SE	KSU	Special	KSU× Special
Color score [a]	3.7	3.7	3.3	3.9	.1	.76	.04	.02
Marbling score [b]	3.1	3.5	3.3	3.6	.2	.18	.10	.84
Firmness score [c]	3.2	3.2	3.1	3.3	.1	.91	.28	.37
Drip loss, %	.6	.6	.6	.7	.1	.42	.26	.12
Thawing loss, %	2.5	2.6	2.99	2.6	.3	.14	.76	.41
Cooking loss, %	25.1	27.2	27.6	25.5	1.2	.77	.98	.12
Shear force, kg	2.73	2.95	2.88	2.73	.15	.41	.78	.12

[a]Scored on a scale of 1 = pale pinkish gray to 5 = dark purplish red (NPPC, 1991) with 3 to 4 as ideal.

[b]Scored on a scale of 1 = partially devoid to 6 = abundant (NPPC 1999) with 3 to 4 as ideal.

[c]Scored on a scale of 1= vary soft and watery to 5 = very firm and dry (1991) with 3 to 4 as ideal.

Table 7. Effects of KSU and Special Premixes on Color Stability of Pork during Display after 45 Days of Storage

	W/O KSU Premixes to 225 lb		W/ KSU Premixes to 225 lb			P-Value		
Item	W/O Special Premix	W/Special Premix	W/O Special Premix	W/Special Premix	SE	KSU	Special	KSU × Special
Day of display								
0								
L*[a]	57.2	58.1	59.1	58.5	.7	.22	.88	.30
a*	20.6	21.3	20.7	20.3	.3	.49	.54	.06
b*	17.2	17.8	17.65	17.4	.4	.84	.54	.17
2								
L*	56.4	57.6	58.45	57.4	.7	.37	.94	.18
a*	17.6	17.7	16.33	17.8	.4	.08	.10	.21
b*	16.5	17.2	17.00	17.0	.3	.72	.39	.33
4								
L*	55.9	57.1	57.9	56.8	.8	.45	.95	.18
a*	15.2	15.2	14.1	15.9	.5	.59	.08	.08
b*	15.2	16.4	16.0	15.8	.6	.87	.37	.28
6								
L*	55.0	55.6	56.7	55.9	.8	.36	.86	.41
a*	13.5	14.3	13.6	14.5	.4	.79	.12	.85
b*	13.8	14.4	14.6	14.3	.6	.70	.82	.54

[a]Hunter 'L' values (lightness) with an acceptable range of 50 to 55, which is considered equal to color score of 2 to 3.

EFFECTS OF FEEDER DESIGN (CONVENTIONAL DRY FEEDER, DRY SHELF-FEEDER, AND WET/DRY SHELF-FEEDER) ON FINISHING PIGS [1]

N. Amornthewaphat, J. D. Hancock, K. C. Behnke [2], L. J. McKinney, C. W. Starkey, D. J. Lee, C. L. Jones, J. S. Park, and D. W. Dean

Summary

Pigs fed from wet/dry shelf-feeders had 6.8% greater ADG compared to those fed from dry shelf-feeders and used 18.3% less water than those fed from conventional feeders.

(Key Words: Feeder Design, Wet/Dry Feeder, Finishing Pigs.)

Introduction

In previous reports from KSU, we demonstrated that wet/dry shelf-feeders supported greater rates and(or) efficiencies of gain compared to conventional dry feeders. However, it has not been demonstrated whether the benefits observed with the wet/dry feeders resulted from the deep-bowl design that might prevent feed wastage or from the wet/dry concept. Thus, we designed an experiment to compare growth performance of finishing pigs when fed from conventional dry feeders and shelf-feeders used to deliver feed in dry or wet/dry form.

Procedures

A total of 180 finishing pigs with an average initial wt of 118 lb was used in the experiment. The pigs were blocked by weight and allotted to the treatments based on sex and ancestry. The pigs were housed in a modified open-front building (16-ft × 6-ft pen) with 50% solid concrete and 50% concrete slat flooring. There were 12 pigs (six barrows and six gilts) per pen and five pens per treatment. Treatments were: 1) a conventional dry feeder (two-hole stainless steel, Model 1/2 no. 2, style B, Smidley Mfg. Co., Dritt, IA); 2) a single-hole shelf-feeder (Model F-5000, Crystal Spring®, Omaha, NE) used dry; and 3) a single-hole shelf-feeder used wet/dry with a water nipple located inside the bowl. In the wet/dry feeders, pigs had the choices of eating either dry feed from the shelf or wet feed from the deep bowl. The pens with conventional dry feeders had one nipple waterer mounted against the wall. Each pen was equipped with a water meter (Neptune, Trident™, 5/8 in. × 3/4 in. , North Kansas City, MO) to determine water disappearance. All pigs were fed the same corn-soybean meal-based diets (Table 1) formulated to .95% lysine, .6% Ca, and .5% P from 119 to 181 lb and .8% lysine, .5% Ca, and .45% P from 181 to 253 lb body weight. The corn was ground with a roller mill (Roskamp Manufacturing, Model D, Ceder Falls, IA), and the diets were fed in meal form (geometric mean particle size of 626 µm).

Pigs and feeders were weighed on d 0, 31, and before slaughter (d 66) to allow calculation of ADG, ADFI, and F/G. From d 55 to 60 of the experiment, the pigs were fed their diet with .25% chromic oxide added as an indigestible marker. On d 60, samples of feces were collected by rectal massage from four pigs per pen. Concentrations of Cr, DM, and N in the feces and diets were determined to allow calculation of apparent

[1]Appreciation is extended to Gro Master, Inc., Omaha, NE, for donation of feeders used in this project.

[2]Department of Grain Science and Industry.

digestibilities of DM and N using the indirect ratio method. On d 66, the pigs were slaughtered, and hot carcass weights were recorded to allow calculation of dressing percentage. Last rib backfat thickness was measured with a ruler at the midline of the split carcass on both sides, and hot carcass weight and last rib backfat thickness were used to calculate fat-free lean index (NPPC, 1994). Finally, the esophageal region of the pigs'stomachs were collected and scored for severity of keratinization and ulceration. The scoring system for keratinization was:.5 = normal, 1 = mild, 2 = moderate, and 3 = severe. The scoring system for ulcers was: .5 = normal, 1 = slight erosion, 2 = ulcer, and 3 = severe ulcer.

All data were analyzed using the GLM procedure of SAS with pen as the experiment unit. Hot carcass weight was used as a covariate for analyses of dressing percentage, last rib backfat thickness, and fat-free lean index. Stomach scores were categorical data; thus, the Cochran-Mantel-Haenszel procedure of SAS (i.e., row mean scores differ test) was used to detect treatment effects.

Results and Discussion

Pigs fed from conventional feeders had ADG, ADFI, and F/G similar to pigs fed from he shelf-feeders (P>.12). However, overall ADG (P<.09) and ADFI (P<.06) tended to be greater when the shelf-feeder was used wet/dry than when it was used dry. Nonetheless, no difference in feed conversion occurred for the overall growth performance.

Pigs fed from the shelf-feeders used 18.3% less water for the overall trial compared to pigs fed from the conventional feeders (P<.08). Also pigs fed from wet/dry feeders used less water than pigs fed from the dry shelf-feeders.

Digestibilities of DM and N, dressing percentage, last rib back fat thickness, and fat-free lean index were not affected by feeder design (P>.57). Finally, scores of stomach lesion (Table 3) were not affected by feeder design.

In conclusion, pigs fed from wet/dry shelf-feeders had the greater ADG and consumed less water compared to pigs fed from dry shelf-feeders. Therefore, the wet/dry-feeding concept, rather than the deep-bowl feeder design, seemed to be of benefit.

Table 1. Compositions of the Basal Diets (As-Fed Basis), %[a]

Ingredient	For 119 to 181 lb	For 181 to 253 lb
Corn	75.61	80.78
Soybean meal (46.5% CP)	20.71	15.87
Lysine-HCl	.16	.15
L-threonine	.05	.03
Soybean oil	1.00	1.00
Monocalcium phosphate	1.00	.84
Limestone	.69	.55
Salt	.35	.35
KSU vitamin premix	.15	.15
KSU mineral premix	.15	.15
Antibitotic[b]	.13	.13

[a]Formulated to .95% lysine, .6% Ca, and .5% P for 119 to 181 lb and .8% lysine, .5% Ca, and .45% P for 181 to 253 lb.
[b]Provided 100g/ton tylosin.

Table 2. Effects of Feeder Design on Growth Performance, Water Usage, Nutrient Digestibility, and Carcass Characteristics in Finishing Pigs[a]

	Feeder Design				Contrasts[c]	
Item	Conventional Dry	Shelf Dry	Shelf Wet/Dry	SE	1	2
For 119 to 181 lb						
ADG, lb	1.99	1.95	2.19	.05	–[d]	.09
ADFI, lb	5.19	4.89	5.50	.15	–	.02
F/G	2.61	2.51	.10	.12	–	–
Water usage, gal/pig/day	1.43	1.28	1.13	.08	.05	–
For 181 to 253 lb						
ADG, lb	2.14	2.12	2.19	.07	–	–
ADFI, lb	6.58	6.41	6.82	.18	–	.13
F/G	3.07	3.02	3.11	.05	–	–
Water usage, gal/pig/day	1.46	1.42	1.18	.08	.12	.06
Overall						
ADG, lb	2.07	2.05	2.19	.05	–	.09
ADFI, lb	5.93	5.74	6.20	.15	–	.06
F/G	2.86	2.80	2.83	.04	–	–
Water usage, gal/pig/day	1.43	1.35	1.15	.07	.08	.08
Apparent digestibility (d 65), %						
DM	89.9	89.6	90.2	.5	–	–
N	87.9	87.7	88.5	.7	–	–
Carcass Characteristics						
Dressing percentage	73.3	73.9	74.7	.3	–	–
Backfat thickness, in	1.03	.96	1.00	.08	–	–
Fat free lean index[b], %	48.2	48.3	48.6	.9	–	–

[a]A total of 180 pigs (12 pigs per pen and five pens per treatment) with an average initial wt of 118 lb and average final wt of 252 lb.

[b]Fat free lean index (NPPC, 1994).was calculated as FFLI = 50.767 + (.035 × hot carcass weight, lb) – (8.979 × backfat thickness, in).

[c]Contrasts were: 1) conventional vs shelf-feeders and 2) dry shelf-feeder vs wet/dry shelf-feeders.

[d]Dashes indicated P>.15.

Table 3. Effects of Feeder Design on Stomach Morphology in Finishing Pigs[a]

	Feeder Design				Contrasts[d]	
Item	Conventional Dry	Shelf Dry	Shelf Wet/Dry	SE	1	2
Stomach Keratinization[b]						
No. observation	60	60	60			
Normal	45	44	47			
Mild	8	11	5			
Moderate	5	5	5			
Severe	2	0	3			
Mean score	.50	.43	.48	.10	–[e]	–
Stomach Ulceration[c]						
No. observation	60	60	60			
Normal	58	59	58			
Mild	1	0	0			
Moderate	0	1	2			
Severe	1	0	0			
Mean score	.08	.04	.08	.05	–	–

[a]A total of 180 pigs (12 pigs per pen and five pens per treatment) with an average initial wt of 118 lb and average final wt of 252 lb was used in the 66 d experiment.

[b]Scoring system was: 0 to .5 = normal; 1 to 1.5 = mild keratosis; 2 to 2.5 = moderate keratosis; and 3 = severe keratosis.

[c]Scoring system was: 0 to .5 = normal; 1 to 1.5 = slight erosions; 2 to 2.5 = ulcers; and 3 = severe ulcers.

[d]Contrasts were: 1) conventional vs shelf-feeders; and 2) dry shelf-feeders vs wet/dry shelf-feeders.

[e]Dashes indicated P>15.

EFFECTS OF FEEDER DESIGN AND PELLET QUALITY ON FINISHING PIGS [1]

N. Amornthewaphat, J. D. Hancock, K. C. Behnke [2], L. J. McKinney, C. W. Starkey, D. J. Lee, C. L. Jones, J. S. Park, and D. W. Dean

Summary

Pigs fed from wet/dry feeders had 2.5% greater ADG and used 26% less water compared to pigs fed from conventional dry feeders. Also, as percentage fines was increased from none to 50%, ADG and digestibilities of DM and N decreased. However, the decreased ADG with increased pellet fines occurred only with the conventional dry feeder.

(Key Words: Pellet Quality, Wet/Dry Feeders, Finishing Pigs.)

Introduction

We have reported previously that pelleting improves rate and(or) efficiency of gain in finishing pigs. However, we also reported that increased amounts of pellet fines reduced the effects of pelleting diets. Other data from our laboratory indicated that wet/dry feeders improved rate and(or) efficiency of growth in finishing pigs fed a meal diet, and that pellet quality might be of lesser significance when a wet/dry feeder is used. Thus, we designed an experiment to determine the effects of pellet quality in pigs fed from wet/dry feeders.

Procedures

A total of 384 finishing pigs (initial BW of 92 lb) was used in an 84-d growth assay. The pigs were blocked by initial weight and allotted to pens based on gender and ancestry with 12 pigs per pen and four pens per treatment. Treatments were arranged as a 2 × 4 factorial with main effects of feeder type (conventional dry feeder vs wet/dry feeder) and diet form (meal, 0, 25, and 50% pellet fines).

Diets were formulate to .95% lysine, .6% Ca, and .5% P for 93 to 194 lb and .8% lysine, .5% Ca, and .45% P for 194 to 260 lb body weight (Table 1). Corn was ground through a roller mill (Roskamp Manufacturing, Model D, Ceder Falls, IA) to particle size of an approximately 600 microns; blended with other ingredients; and pelleted through a 30-horsepower pellet mill (30 HD Master Model, California Pellet Mill, San Francisco, CA) equipped with die having 3/16-in. opening. Conditioning temperatures were 180 and 185°F for the diets. To generate the desired amount of fines, the pellets were mechanically challenged by mixing in a Forberg® mixer. Fines were characterized as material that would pass through a Tyler #5 sieve (.16-in. openings).

The pigs were housed in 16-ft × 6-ft pen with 50% solid concrete and 50% slotted flooring. Feeders were a two-hole, dry feeder (model 1/2 no. 2 style B, Smidley Mfg. Co, Dritt, IA) and a single-hole, wet/dry shelf-feeder with a nipple waterer located at the base of the trough (Crystal Spring®, model F-5000, Omaha, NE). The pens with dry feeders had one nipple waterer mounted against the wall. Each pen was equipped with a water meter (Neptune,

[1]Appreciation is extended to Gro Master, Inc., Omaha, NE, for donation of feeders used in this project.

[2]Department of Grain Science and Industry.

Trident™, 5/8 in. × 3/4 in., North Kansas City, MO) to determine water disappearance.

From d 75 to 80 of the experiment, pigs were fed their diets with .25% chromic oxide added. On d 80, samples of feces were collected by rectal massage from four pigs in each pen. Concentration of Cr, DM, and N in the feces and diets were determined to allow calculation of apparent digestibilities of DM and N. On d 82, the pigs were slaughtered and hot carcass weights were recorded to allow calculation of dressing percentage. Last rib backfat thickness was measured with a ruler on each side of the split carcass at the midline. Hot carcass weight and last rib backfat thickness were used to calculate fat-free lean index (NPPC, 1994). Finally, stomachs were collected and scored for severity of esophagogastric ulcers and keratinization. The scoring system for keratinization was: 0 = normal, 1 = mild keratosis, 2 = moderate keratosis, and 3 = severe keratosis. The scoring system for ulcers was: 0 = normal, 1 = slight erosion, 2 = ulcers, and 3 = severe ulcers.

All data were analyzed using the GLM procedure of SAS with pen as the experiment unit. Hot carcass weight was used as a covariate for analyses of dressing percentage, last rib backfat thickness, and fat-free lean index. Stomach scores were categorical data; therefore, the Cochran-Mantel-Haenszel procedure of SAS (i.e., row mean scores differ test) was used to detect treatment effects.

Results and Discussion

Pigs fed from wet/dry feeders had 2.5% greater ADG (P<.01) and used 26% less water (P<.02) vs pigs fed from conventional dry feeders (Table 2). Also, pigs fed pelleted diets had 3% greater ADG (P<.09) than pigs fed meal diets. As the amount of fines was increased from none to 50%, ADG (P<.04) and digestibilities of DM (P<.01) and N (P < .01) decreased. However, at least for ADG, the negative effects of pellet fines occurred primarily in pigs fed from the conventional dry feeders (feeder type × linear effect of fines, P<.03).

Dressing percentage was not affected by feeder type or diet form (P<.07), but pelleting increased last rib backfat thickness when the diet was fed in a conventional dry feeder (conventional vs wet/dry × meal vs pellets, P<.02). As a result of the greater last rib backfat thickness, pigs fed from wet/dry feeders had a slightly lower fat-free lean index than pigs fed from conventional dry feeders (P<.04).

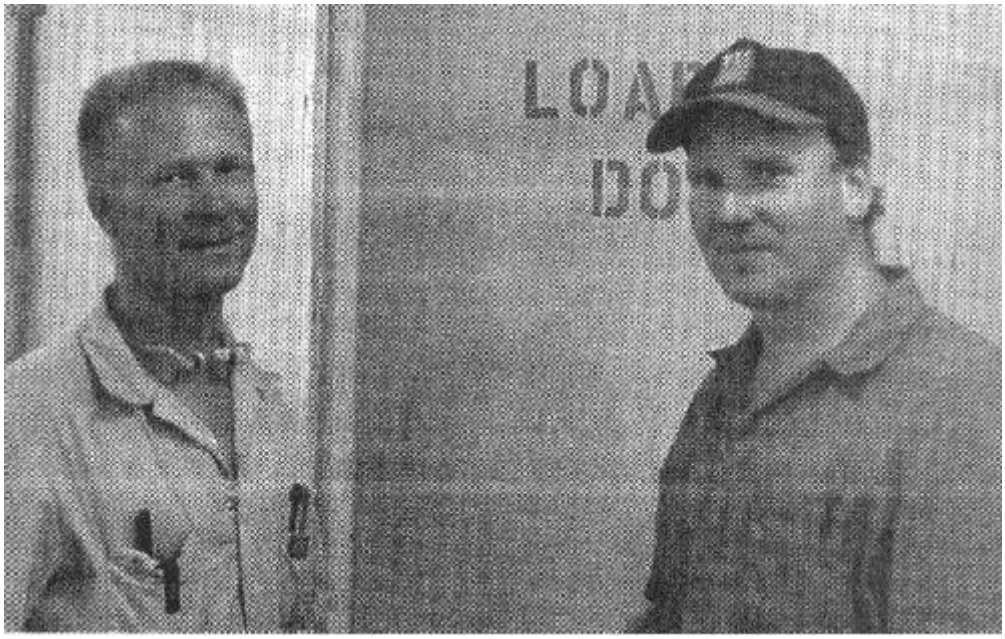
The incidence and severity of stomach ulcers (Table 3) were less when pigs were fed a meal diet compared to pellets (P<.001). Also, stomach ulceration scores decreased as percentage fines was increased (linear effect, P<.04) and the diet became more like the meal control. Feeder design did not affect the incidence or severity of stomach lesions (P>.15).

In conclusion, pelleting tended to improve ADG and F/G when diets were fed from a conventional dry feeder. Also, pellet quality was an issue when conventional feeders were used. Pigs fed from the wet/dry feeders tended to have greater ADG and feed intake and less water usage vs pigs fed from the conventional dry feeders. However, pelleting and pellet quality had minimal effect on growth performance in finishing pigs fed from wet/dry feeders.

Table 1. Compositions of the Basal Diets[a]

Ingredient, %	For 93 to 194 lb	For 194 to 260 lb
Corn	75.62	80.78
Soybean meal (46.5% CP)	20.71	15.62
Lysine-HCl	.16	.15
L-threonine	.05	.03
Soybean oil	1.00	1.00
Monocalcium phosphate	1.00	.84
Limestone	.69	.55
Salt	.35	.35
KSU vitamin premix	.15	.15
KSU mineral premix	.15	.15
Antibitotic[b]	.13	.13

[a]Formulated to .95% lysine, .6% Ca, and .5% P for 93 to 194 lb and .8% lysine, .5% Ca, and .45% P for 194 to 260 lb.
[b]Provided 100g/ton tylosin.



Mark Nelson, Farm Manager, and Robert Beckley, Farrowing House Manager.

Table 2. Effects of Feeder Design and Pellet Quality on Growth Performance, Water Disappearance, Nutrient Digestibility, and Carcass Characteristics in Finishing Pigs[a]

	Conventional Dry Feeder				Wet/Dry Feeder											
		% Fines				% Fines				Contrasts[b]						
Item	Meal	0%	25%	50%	Meal	0%	25%	50%	SE	1	2	3	4	5	6	7
For 94 to 194 lb																
ADG, lb	1.94	2.00	1.95	1.90	2.12	1.98	2.00	2.02	.04	.02	-[d]	-	-	.08	.13	-
ADFI, lb	5.05	5.09	5.03	4.96	5.42	5.18	5.14	5.16	.09	.01	.09	-	-	.13	-	-
F/G	2.60	2.55	2.58	2.61	2.56	2.62	2.57	2.55	.05	-	-	-	-	-	-	-
Water usage, gal, pig/day	1.8	2.3	2.0	1.9	1.6	1.3	1.4	1.5	.1	.01	-	-	-	.12	.06	-
For 194 to 260 lb																
ADG, lb	2.11	2.36	2.34	2.20	2.10	2.23	2.45	2.24	.06	-	.01	-	.03	-	-	-
ADFI, lb	6.42	6.39	6.50	6.48	6.46	6.58	6.64	6.50	.21	-	-	-	-	-	-	-
F/G	3.04	2.71	2.78	2.95	3.08	2.95	2.71	2.90	.12	-	.03	-	-	-	-	-
Water usage, gal, pig/day	2.2	2.6	2.3	2.3	2.1	1.5	2.0	1.7	.2	.01	-	-	-	.13	-	-
Overall																
ADG, lb	1.96	2.10	2.04	1.98	2.07	2.05	2.12	2.05	.03	.01	.09	.04	.10	.12	.03	-
ADFI, lb	5.50	5.49	5.42	5.41	5.58	5.53	5.58	5.58	.14	-	-	-	-	-	-	-
F/G	2.81	2.61	2.66	2.73	2.70	2.70	2.63	2.72	.06	-	-	-	-	-	-	-
Water usage, gal, pig/day	2.0	2.4	2.1	2.1	1.8	1.4	1.6	1.6	.2	.02	-	-	-	.05	-	-
Apparent digestibility, %																
DM	88.6	87.8	88.8	85.7	87.3	88.5	87.2	86.5	.7	-	-	.01	.12	-	-	.05
N	87.6	86.0	87.5	84.4	85.6	87.1	84.8	83.6	1.0	-	-	.01	-	-	-	.05
Carcass Characteristics																
Dressing percentage	73.9	73.5	73.4	73.7	73.7	73.9	72.6	73.3	.4	-[h]	-	-	-	-	-	-
Backfat thickness, in	.90	1.02	.96	1.01	1.04	1.00	1.04	1.00	.1	.03	-	-	-	.02	-	-
Fat free lean index, %[c]	49.4	48.2	48.8	48.3	48.3	48.4	48.0	48.3	.3	.04	.03	-	-	.07	-	.08

[a]A total of 384 pigs (12 pigs/pen and four pens/treatment) with an average initial BW of 93 lb and an average final BW of 260 lb.
[b]Contrasts were: 1) dry vs wet/dry; 2) meal vs pellets; 3) linear effect of fines; 4) quadratic effect of fines; 5) feeder type × meal vs pellets; 6) feeder type × linear effect of fines; and 7) feeder type × quadratic effect of fines.
[c]Fat free lean (NPPC, 1994) was calculated as FFL = 50.767 + (.035 × hot carcass weight, lb) - (8.979 × backfat thickness, in).
[d]Dashes indicated P>.15.

Table 3. Effects of Feeder Design and Pellet Quality on Stomach Lesions in Finishing Pigs[a]

	Conventional Dry Feeder				Wet/Dry Feeder											
		% Fines				% Fines				Contrasts[b]						
Item	Meal	0%	25%	50%	Meal	0%	25%	50%	SE	1	2	3	4	5	6	7
Stomach Keratinization[c]																
No. of observations	45	42	47	42	43	40	43	46								
Normal	30	8	7	9	28	10	19	9								
Mild	12	18	24	25	10	18	14	23								
Moderate	2	10	11	7	5	11	10	12								
Sever	1	6	5	1	0	1	0	2								
Mean scores[d]	.31	1.21	1.16	.84	.37	1.00	.71	1.03	.11	-[g]	.001	-	-	-	.08	.02
Stomach Ulceration[e]																
No. of observations	45	42	47	43	43	41	43	46								
Normal	44	28	34	38	39	27	35	33								
Erosion	0	4	8	1	3	7	5	4								
Ulcer	0	7	3	2	1	4	3	3								
Severe ulcer	1	3	2	2	0	3	0	2								
Mean scores[f]	.06	.63	.40	.24	.08	.56	.22	.49	.10	-	.001	.04	.07	-	.13	.14

[a]A total of 384 pigs (12 pigs/pen and four pens/treatment) with an average initial BW of 93 lb and an average final BW of 260 lb.
[b]Contrasts were: 1) dry vs wet/dry; 2) meal vs pellets; 3) linear effect of fines; 4) quadratic effect of fines; 5) feeder type × meal vs pellets; 6) feeder type × linear effect of fines; and 7) feeder type × quadratic effect of fines.
[c]Scoring system was 0= normal; 1= mild keratosis; 2 = moderate keratosis; and 3= severe keratosis.
[d]Cochran-Mantel-Haenszel statistic, row mean scores differ test was P<.001.
[e]Scoring system was 0 = normal; 1= slight erosion; 2 = ulcers; and 3= severe ulcers.
[f]Cochran-Mantel-Haenszel statistic, row mean scores differ test was P<.001.
[g]Dashes indicated P>.15.

EFFECTS OF EXPANDING AND PELLETING DIETS ON FINISHING PIGS FED FROM WET/DRY FEEDERS[1]

N. Amornthewaphat, J. D. Hancock, K. C. Behnke, L. J. McKinney, C. W. Starkey, D. J. Lee, C. L. Jones, J. S. Park, and D. W. Dean

Summary

Pigs fed pelleted and expanded diets from wet/dry feeders had 4.4% greater ADG and 7.9 % greater efficiency of gain than pigs fed a mash diet. Also, trends for greater efficiencies of gain occurred among pigs fed expanded pellets vs standard pellets and expandate vs expanded pellets.

(Key Words**:** Expanding, Pelleting, Wet/Dry Feeders, Finishing Pigs.)

Introduction

Previously reported data from our lab demonstrated that pelleting improved efficiency of growth by about 6% compared to meal diets. However, in other experiments, we observed similar improvements in efficiency of gain when a mash diet was fed through wet/dry feeders. Thus, we designed an experiment to determine if thermal processing (pelleting and expanding) are of benefit when pigs are fed from wet/dry feeders.

Procedures

A total of 208 finishing pigs (initial wt of 133 lb) was used in a 55-d growth assay. The pigs were blocked by initial weight and allotted to pen (based on gender and ancestry)with 13 pigs per pen and four pens per treatment. Treatments were: 1) mash, 2) standard pellet, 3) expandate, and 4) expanded pellets. The pigs were house in 6-ft × 16-ft pens with 50% solid concrete and 50% concrete slat flooring. Each pen had a wet/dry shelf feeder (Crystal Spring®, model F-5000, Omaha, NE) with a nipple waterer located at the base of the trough. Water meters (Neptune, Trident™, 5/8 in. × 3/4 in., North Kansas City, MO) were installed in all pens to allow measurement of water disappearance.

Corn was ground through a roller mill (Roskamp Manufacturing, Model D, Ceder Falls, IA) to approximately 600 microns and used in diets formulate to .95% lysine, .6% Ca, and .5% P for 133 to 194 lb and .8% lysine, .5% Ca, and .45% P for 194 to 248 lb body weight. The pelleted diets were processed through a 30-horsepower pellet mill (30 HD Master Model, California Pellet Mill, San Francisco, CA) equipped with a die having 3/16-in. opening. Conditioning temperature was 180°F, and retention time in the conditioning chamber was 10 to15 seconds. Expandate was steam-conditioned processed through a 100 horsepower expander (Amandus-Kahl, Model OE15.2) at 333 psi and ground through a hammermill equipped with a 1/2-in screen. Expanded pellets were steam conditioned to 180°F for 10 to15 seconds at 333 psi and pelleted in the same pellet mill used for standard pellets. Production rate was held constant at 3000 lb/hour.

From d 46 to 51 of the experiment, pigs were fed their diets with .25% chromic oxide added as an indigestible marker. On d 51, samples of feces were collected (by rectal massage) from four pigs in each pen, pooled, and frozen for later analyzes. Concentration

[1]Appreciation is extended to Gro Master, Inc., Omaha, NE, for financial assistance with this project.

of Cr, DM, and N in the feces and diets were determined to allow calculation of apparent digestibilities of DM and N.

On d 55, the pigs were slaughtered and hot carcass weights were recorded to allow calculation of dressing percentage. Last rib backfat thickness was measured with a ruler at the midline on each half of the split carcass. Hot carcass weight and last rib backfat thickness were used to calculate percentage fat-free lean (NPPC, 1994).

All data were analyzed using the GLM procedure of SAS with pen as the experimental unit. Hot carcass weight was used as a covariate for analyses of dressing percentage, last rib backfat thickness, and fat-free lean index.

Results and Discussion

For 133 to 194 lb, ADG was not affected by the dietary treatments, but pigs fed the thermally processed diets (pellets, expandate, and expanded pellets) tended (P<.10) to have greater efficiency of growth. From 194 to 248 lb, pigs fed thermally processed diets had 9.4% greater ADG and 11.4% lower F/G (P<.001) compared to those fed the mash control. For the overall experiment (133 to 248 lb), pigs fed thermally processed diets had 4.4% greater ADG (P<.04) and 7.9% greater efficiency of gain (P<.001) vs those fed the mash control. Expanding increased efficiency of growth beyond that seen with standard pellets (P<.01), and expandate improved efficiency beyond that observed for expanded pellets (P<.02). Pigs fed thermally processed diets had 3.7 and 4.6 % greater digestibilities of DM and N compared to pigs fed the mash diet (P<.001) but digestibility of DM was greatest for pigs fed standard pellets (P<.01).

Pigs fed thermally processed diets had greater (P<.001) dressing percentage than pigs fed the mash control, and pigs fed expanded pellets had the greatest (P<.002) dressing percentage of all treatments. However, last rib backfat thickness and percentage carcass lean were not affected by diet (P>.57). In conclusion, thermally processed diets (pelleted and expanded) improved growth performance and digestibility of nutrients in finishing pigs fed from wet/dry feeders. Of the three thermal treatments, expandate supported the best gain/feed.

Table 1. Diet Compositions[a]

Ingredient, %	For 133 to 194 lb	For 194 to 248 lb
Corn	75.62	80.78
Soybean meal (46.5% CP)	20.71	15.62
Soybean oil	1.00	1.00
Lysine-HCl	.16	.15
L-threonine	.05	.03
Monocalcium phosphate	1.00	.84
Limestone	.69	.55
Salt	.35	.35
KSU vitamin premix	.15	.15
KSU mineral premix	.15	.15
Antibitotic[b]	.13	.13

[a]Formulated to .95% lysine, .6% Ca, and .5% P for 133 to 194 lb and .8% lysine, .5% Ca, and .45% P for 194 to 248 lb.
[b]Provided 100g/ton tylosin.

Table 2. Effects of Expanding and Pelleting Diets for Finishing Pigs Fed from Wet/Dry Shelf-Feeders[a]

						Contrasts[b]		
Item	Mash	Standard Pellet	Expandate	Expanded Pellet	SE	1	2	3
For 133 to 194 lb								
ADG, lb	2.15	2.23	2.13	2.13	.06	–[c]	–	–
ADFI, lb	5.80	5.85	5.28	5.46	.16	–	.08	–
F/G	2.70	2.62	2.48	2.56	.07	.10	–	–
Water usage, gallons/pig	1.7	1.7	1.5	1.9	.1	–	–	–
For 194 to 248 lb								
ADG, lb	1.88	2.01	2.06	2.08	.05	.01	–	–
ADFI, lb	6.33	6.27	6.06	6.32	.11	–	–	.13
F/G	3.37	3.12	2.94	3.04	.05	.001	.06	.06
Water usage, gallons/pig	1.9	1.9	1.7	2.1	.3	–	–	–
Overall								
ADG, lb	2.02	2.12	2.11	2.10	.03	.04	–	–
ADFI, lb	6.06	6.05	5.67	5.88	.11	–	.08	–
F/G	3.01	2.86	2.70	2.81	.03	.001	.01	.02
Water usage, gallons/pig	1.8	1.8	1.6	2.0	.3	–	–	–
Apparent digestiblity, %								
DM	87.5	91.7	89.9	90.6	.4	.001	.01	.06
N	84.6	89.2	87.6	88.8	.6	.001	–	–
Carcass Characteristics								
Dressing percentage	72.9	73.5	73.3	74.2	.1	.001	–	.002
Last rib fat thickness, in	.91	.93	1.01	.93	.13	–	–	–
Fat free lean index, %	49.1	49.0	48.2	49.1	.3	–	–	–

[a]A total of 208 finishing pigs (13 pigs/pen and four pens/treatment) with an average initial wt of 133 lb and average final wt of 248 lb.

[b]Contrasts were: 1) nonthermal (mash) vs thermal processing (pelleting and expanding); 2) standard pellets vs expandate and expanded pellets; and 3) expandate vs expanded pellets.

[c]Dashes indicated P>.15.

SORTING GROWING-FINISHING PIGS BY WEIGHT FAILS TO IMPROVE GROWTH PERFORMANCE OR WEIGHT VARIATION

P. R. O'Quinn, S. S. Dritz[1], R. D. Goodband, M. D. Tokach, J. C. Swanson, J. L. Nelssen, and R. E. Musser

Summary

A trial was conducted to determine the effects of sorting pigs by body weight at placement on growth performance and weight variation at finishing. Unsorted pigs and heavy sorted pigs had higher ADG than medium or light sorted pigs. By the end of the trial, final body weights ranked in the following descending order: heavy sorted, unsorted, medium sorted, and light sorted. Final weights of unsorted pigs were heavier than the average final weight of all sorted pigs. Additionally, differences in body weight variation were not detectable by the end of the study. These data suggest that sorting pigs uniformly by weight to pens has little effect on final variability in individual body weights and placing pigs into pens regardless of weight may increase the amount of pork produced from a system and reduce turnaround time in barns.

(Key Words: Growing-Finishing Pigs, Sorting, Growth Performance, Weight Variation.)

Introduction

Sorting and grouping pigs by similar body weights is a common management technique thought to minimize variation in final pig body weights. Therefore, sorting by weight is thought to achieve packer weight specifications more efficiently. However, few data are available to support these assumptions. Therefore, this study was undertaken to determine the effects of initial within-pen weight variation on growth performance and weight variation at marketing.

Procedures

Two sequential trials were conducted. In each trial, we allotted 192 crossbred (PIC L326 or 327 boars × C22 sows) barrows and gilts, approximately 14 weeks of age and 75 lb, to one of four experimental groups:

Uniformly heavy; initially weighing 81.7±3.09 lb;

Uniformly medium; initially weighing 75.0±1.71 lb;

Uniformly light; initially weighing 66.5±4.47 lb;

High variation, medium weight (Unsorted), initially weighing 74.6 ± 6.96 lb (intended to have beginning weight similar to that of uniformly medium pigs but quadruple the initial variation in weight).

In each trial, approximately 250 pigs were available to select from, and in each case, pigs weighing more than three standard deviations from the group average (about 12 pigs) were removed from consideration. Thus, extremely heavy or extremely light pigs were not used. The remaining pigs not used in the study were selected across the weight groups so as not to disrupt the normal weight distribution. In each trial, pigs were utilized from a single farrowing group that farrowed over a 7-d period. Sex and ancestry were balanced within and across blocks

[1]Food Animal Health and Management Center.

of pens. Pigs were allocated to experimental groups in the following manner. Barrows and gilts were sorted separately according to body weight and divided into three weight groups (heavy, medium, and light). The unsorted pens were created by taking equal thirds from each of the uniformly heavy, medium, and light groups. Sex was balanced such that each third of the unsorted pens and the corresponding third of each sorted pen contained equal numbers of barrows and gilts. Thus, comparisons could be made (without confounding by age, sex, or ancestry) between sorted and unsorted pens and among the heavy, medium, and light thirds of the unsorted pens to the corresponding uniformly heavy, medium, and light pens. Pigs were housed in a modified open-front finishing barn with 6 ft × 16 ft partially slatted pens (50% slatted and 50% solid). Each pen contained a single nipple waterer and a two-hole self-feeder to allow pigs ad libitum access to water and feed, respectively. Each trial consisted of four blocks of the four experimental groups with pigs housed 12 per pen providing 8 sq ft/pig. Thus, the overall experiment included eight observations per treatment group.

Pigs were fed nutritionally adequate grain sorghum-soybean meal-based diets in three phases with decreasing nutrient density as pig weight increased. Pigs and feeders were weighed upon initiation of the trials and again at d 7, 14, 21, 28, 56, 70, and 91 for the determination of pen ADG, ADFI, and F/G. Within-pen variation (standard deviation) in individual body weight also was determined for each pen.

Data are reported as LS means and were analyzed as a randomized complete block with pen as the experimental unit using the GLM procedure of SAS. Means were separated using the Least Significant Difference (LSD) procedure of SAS. A preplanned nonorthogonal contrast was used to compare the average weight of the three sorted-pen categories of pigs against that of the unsorted pens of pigs.

A second statistical model was used to compare the ADGs of the heavy, medium, and light thirds of the unsorted pens of pigs to their respective sorted counterpart pens. Therefore, the experimental unit for the unsorted pigs was four pigs per pen corresponding to the three uniformly sorted weight categories and pen for the uniformly sorted groups. Again, the ADGs of these six groups were compared statistically also by the LSD procedure. All probability values were considered significant at $P<.05$.

Results and Discussion

The uniformly heavy and medium pigs and the unsorted pigs had similar ($P>.05$) ADG and ADFI from d 0 to 14 and d 0 to 28 (Table 1). However, both uniformly heavy and unsorted pigs grew faster ($P<.05$) than uniformly light pigs, with uniformly medium pigs being intermediate during these same time intervals. Growth performance was similar ($P>.05$) between sorted and unsorted pigs during these two periods. For the overall growth period (d 0 to 91), uniformly heavy and unsorted pigs had similar ADG ($P>.05$), and both were higher ($P<.05$) than ADG of the uniformly medium and light pigs, which were similar ($P>.05$). Additionally, the ADG of unsorted pigs was higher ($P = .03$) than the mean ADG of sorted pigs. No differences ($P>.05$) were observed for ADFI over the total trial, and F/Gs were similar ($P>.05$) for uniformly heavy and medium and unsorted pigs, lowest for uniformly light pigs, and intermediate for uniformly medium pigs.

As expected, average pig weights at d 0 were highest ($P<.05$) for uniformly heavy pigs, lowest for uniformly light pigs, and similar and intermediate for uniformly medium and unsorted pigs (Table 1). This trend continued through d 70. However, at the termination of the study (d 91), uniformly heavy pigs were heaviest, followed by unsorted, uniformly medium, and uniformly light pigs. All four groups were significantly ($P<.05$) different, and the final weight of unsorted pigs was heavier ($P=.03$) than the average final weight of all sorted pigs.

Within-pen variation (Table 2) followed a pattern similar to that of body weights.

Initial variation was smallest (P<.05) for uniformly medium pigs, reflecting the average of the total population of pigs. Additionally, the variations of the four experimental groups were significantly different (P<.05). As time on test progressed, differences in within-pen variation among the three sorted groups diminished.

An examination of the matched groupings of pigs for ADG (Table 3) revealed that sorting pigs by similar body weights may not be necessary to achieve maximal production from a barn of finishing pigs. From d 0 to 91, uniformly heavy pigs and the heavy and medium thirds of the unsorted pens had the highest (P<.05) ADG. The uniformly medium pigs were intermediate, and the uniformly light pigs and light third of the unsorted pens had the lowest ADG.

These data indicate that sorting pigs uniformly by weight may not be necessary for maximum growth performance. Endpoint variability in individual pig weights within a pen is unaffected by sorting strategy. Additionally, eliminating sorting of finishing pigs upon placement may improve throughput (amount of pork produced) within a production system. The definitive reason for these observations is not readily apparent. However, the shifting in the population was primarily due to the growth performance of the medium pigs in the unsorted pens of pigs. The medium pigs in pens containing light and heavy pigs grew substantially faster than medium pigs penned uniformly by body weight. Thus, these responses could potentially be due to the development of a social hierarchy. However, additional research is needed to confirm this hypothesis.

Table 1. Growth Performance and Average Pig Weights[a]

	Sorted Pens					Probability
Item	Heavy	Medium	Light	Unsorted	CV	Sorted vs Unsorted
day 0 to 14						
ADG, lb	2.29[b]	2.23[bc]	2.15[c]	2.27[b]	3.84	.24
ADFI, lb	4.76[b]	5.18[bc]	5.39[c]	5.15[bc]	8.71	.84
F/G	2.07[b]	2.32[cd]	2.50[d]	2.28[c]	8.57	.81
day 0 to 28						
ADG, lb	2.25[b]	2.18[bc]	2.13[c]	2.23[b]	3.73	.20
ADFI, lb	5.14[b]	5.44[bc]	5.58[c]	5.44[bc]	6.33	.72
F/G	2.32[b]	2.53[bc]	2.66[c]	2.46[bc]	9.32	.71
day 0 to 91						
ADG, lb	2.08[b]	2.02[c]	2.00[c]	2.08[b]	2.08	.03
ADFI, lb	5.89	5.87	6.02	5.95	5.37	.84
F/G	2.85[b]	2.93[bc]	3.02[c]	2.88[bc]	5.46	.46
Average Pig Weights on Day, lb						
0	81.7[b]	75.0[c]	66.5[d]	74.6[c]	1.29	.64
7	99.0[b]	91.9[c]	82.8[d]	91.9[c]	1.71	.30
14	115.0[b]	107.3[c]	97.7[d]	107.6[c]	1.56	.20
21	130.0[b]	122.1[c]	112.2[d]	122.2[c]	1.77	.39
28	145.6[b]	137.0[c]	127.0[d]	138.0[c]	2.04	.22
56	206.9[b]	195.4[c]	185.8[d]	197.4[c]	1.46	.27
70	232.9[b]	222.1[c]	211.7[d]	224.7[c]	2.35	.26
91	272.1[b]	259.7[c]	249.6[d]	264.4[e]	1.58	.03

[a]Values are means of eight replicate pens (with 12 pigs per pen) per treatment (initial average pen weight of 74.5 lb). The CV reported represents variation among pen means. The probability for sorted vs unsorted was determined by means of a nonorthognal contrast comparing the mean of the heavy, medium, and light pens to that of the sorted pens.
[b,c,d,e]Means in a row with different superscripts differ (P<.05).

Table 2. Average Within-Pen Weight Variation (SD)[a]

	Sorted Pens					Probability
Time	Heavy	Medium	Light	Unsorted	CV	Sorted vs Unsorted
day 0	3.09[b]	1.71[c]	4.47[d]	6.96[e]	15.61	.0001
day 7	4.55[bc]	3.13[c]	5.85[d]	8.50[e]	25.34	.0001
day 14	5.29[b]	4.04[c]	6.21[b]	9.17[d]	18.98	.0001
day 21	6.37[bc]	5.15[c]	7.26[b]	9.76[d]	19.48	.0001
day 28	7.84[bc]	6.34[c]	8.69[b]	11.01[d]	18.16	.0001
day 56	10.88[bc]	9.97[c]	13.15[bd]	15.11[d]	22.01	.003
day 70	12.52	13.24	15.47	16.50	26.60	.09
day 91	16.24	16.67	20.40	19.22	28.64	.50

[a]The SD values are the means of eight replicate pens (with 12 pigs per pen) per treatment (initial average pen weight of 74.5 lb). The CV reported represents variation among pen means. The probability for sorted vs unsorted was determined by means of a nonorthognal contrast comparing the means of the heavy, medium, and light pens to that of the sorted pens.
[b,c,d,e]Means in a row with different superscripts differ (P<.05).

Table 3. Average Daily Gains (lb) of Sorted Pens or Heavy, Medium, and Light Thirds of Unsorted Pens[a]

	Sorted Pens			Unsorted Groups			
Time	Heavy	Medium	Light	Heavy	Medium	Light	CV
day 0 to 14	2.29[bc]	2.23[bcd]	2.15[cd]	2.34[b]	2.32[b]	2.16[cd]	5.79
day 0 to 28	2.25[b]	2.18[bc]	2.13[c]	2.27[b]	2.25[b]	2.08[c]	5.24
day 0 to 91	2.08[bc]	2.02[cd]	2.00[d]	2.11[b]	2.13[b]	1.99[d]	3.56

[a]Values are means of eight replicate pens (with 12 pigs per pen for the sorted pens and 4 pigs per pen for the unsorted pens.) per treatment. The CV reported represents variation among pen means. The probability for sorted vs unsorted was determined by means of a nonorthognal contrast comparing the mean of the heavy, medium, and light pens to that of the sorted pens. The unsorted groups refer to the heavy, medium, and light thirds of each unsorted pen, respectively.
[b,c,d]Means in a row with different superscripts differ (P<.05).

USE OF INFRARED THERMOGRAPHY TO EVALUATE DIFFERENCES IN MEAN BODY SURFACE TEMPERATURE AND RADIANT HEAT LOSS IN GROWING PIGS

J. A. Loughmiller, M. F. Spire[1], M. D. Tokach, S. S. Dritz[1], J. L. Nelssen, R. D. Goodband, S. B. Hogge[1], and B. W. James

Summary

Eighty barrows were used in two experiments to determine the relationship between feed intake or dietary energy concentration and mean body surface temperature (MBST) and mean body surface radiant heat loss (MBSL) as measured using infrared thermographic images. In Exp. 1, feed intake level was varied. As expected, pigs with higher feed intake grew faster. The faster growing pigs had higher MBST and MBSL. In Exp. 2, pigs (initially 130 lb) were allotted to one of four dietary energy levels (1,250 ME/lb, 1,360 ME/lb, 1,475 ME/lb, 1,590 ME/lb). Increasing dietary ME levels increased ADG, G/F, ME intake, MBST, and MBSL. These experiments indicate that infrared thermography can detect MBST and MBSL changes in growing pigs caused by changes in dietary intake or energy level.

(Key Words: Infrared Thermography, Dietary Energy, Growing Pigs.)

Introduction

Recent research has indicated that infrared thermography can reliably identify pigs exhibiting a febrile condition following *Actinobacillus pleuropneumoniae* infection. The rise in MBST associated with the febrile state was observed in comparison to nonchallenged controls during an 18 h period of feed withdrawal for both challenged and nonchallenged pigs. Because adaptive responses to disease or stress typically involve feed intake reductions, it is unknown if the elevated MBST associated with the febrile condition would mask the relative reduction in MBST associated with this feed intake reduction when compared to healthy pigs with full feed consumption.

Additionally, different growth rates, changes in feed intake, and dietary nutrient content affect metabolic heat production in healthy pigs. Because of these differences, it may be possible to detect associated differences in MBST and MBSL and relate them to growth performance. Thus, our objective was to measure the changes in MBST and MBSL associated with growth performance in healthy pigs subjected to changes in feed intake or dietary nutrient profile.

Procedures

Eighty crossbred barrows (326 × C22, PIC, Franklin KY) were selected from the Kansas State University Swine Teaching and Research Center. The pigs were housed in individual pens in an environmentally controlled finishing building with mechanical ventilation. Each pen (5 ft × 5 ft with totally slatted flooring) contained a single-hole, dry feeder and a single-nipple waterer. Pigs were blocked at the start of each experiment by initial weight and allotted to dietary treatment. Pigs in all experiments were allowed ad libitum water consumption.

All diets were corn and soybean meal based with added alfalfa meal, wheat midds, or soybean oil within treatment in Exp. 2 (Table 1). Diets were formulated to meet or exceed current recommendations with the exception of dietary ME (Exp. 2). Total and

[1]Food Animal Health and Management Center.

true digestible nutrient values from NRC (1998) were used, allowing similar total Ca:P ratios across treatments in all experiments and similar calculated true digestible lys:Mcal ME ratios across treatments within Exp. 2.

Imaging equipment consisted of a high-resolution, short-wave (3-5 µm), radiometric, infrared thermal imaging camera. Pigs were imaged while standing unrestrained in their pen. Images were taken at a distance of 6 ft perpendicular to the side of each pig. Mean body surface temperature was calculated from an approximately 3,500 pixel image of a 6 H × 10 W inch area from a standard location on each pig. The mean temperature for the area was calculated to compare changes in mean body surface temperature as affected by experimental treatment. In addition, ambient temperatures were measured at each sampling from six locations at pig height equally spaced throughout the room. These ambient temperatures were used to correct the daily MBST of the pigs using an adjustment factor of ± 0.4 per degree above or below 68°F ambient temperature.

Mean body surface radiant heat loss from the pig was calculated from the equation $Qr = Ar\ E\ \sigma\ (Te^4 - Ts^4)$, where Qr = radiant heat exchange; Ar = effective radiant surface area (m^2); E = emissivity (assumed to be 1.0); σ = Stefan-Boltzman constant; Te = average absolute radiant environmental temperature, K; and Ts = average absolute radiant surface temperature, K.

Experiment 1. Eighty barrows (initially 55 ± 6 lb) were blocked by initial weight in a randomized complete block design and allotted to one of four feed-intake levels within each block for 7 d. The feed intake levels were based upon the NRC (1998) maintenance ME estimate of $106 \times BW^{0.75}$ (kg) for growing swine. Pigs were allowed 0.75 × ME of maintenance (MEm), 1.5 × MEm, 2.5 × MEm, and ad libitum access. All pigs were evaluated daily, and feed was provided at 0730. Orts were collected daily to determine net feed intake. Following a 4 d adaptation period to the intake regimens, images were collected three times per day at 0700, 1100, 1900 h on d 5, 6, and 7. These times were chosen to measure changes in body temperature immediately prefeeding, 3 h after feeding, and 10 h after feeding.

Data were arranged in a randomized complete block design. Pigs were blocked by initial weight and were assigned randomly to individual treatments within each block. For analysis of change in mean body surface temperature and heat loss over time, a PROC MIXED procedure with repeated measures and a Satterthwaite error correction was used. The repeated measures model included the treatment effect, the effects of time period, and the treatment × time period interaction. Comparisons between treatments, within sampling times were made when a significant *F*-test for the treatment × time interaction was found. Individual pig was the experimental unit. Periodic samples by pig were used for the repeated measures. An interactive matrix language procedure was used to determine orthogonal linear and quadratic polynomial contrasts for unequally spaced treatments. To determine the approximate ME intake of the ad libitum-fed pigs, their average ME intake during the growth assay period was calculated relative to their individual calculated MEm requirement (ad libitum intake averaged 3.8 × MEm). The average intake relative to MEm then was used to determine the orthogonal contrasts. The orthogonal contrasts measured the effects of feed intake regimen on growth performance, MBSL, and MBST.

Experiment 2. The 80 pigs from Exp. 1 (initially 130 ± 11 lb) were blocked by initial weight in a randomized complete block design and assigned within block to one of four dietary treatments for 20 d. Pens, feed, and water were as described above. Experimental diets were formulated to provide moderately low, slightly low, adequate, and moderately excess (1,250 ME/lb, 1,360 ME/lb, 1,475 ME/lb, 1,590 ME/lb, respectively) daily energy intake levels based upon expected daily feed intake and calculated dietary nutrient content. After reallotment to the new pen and treatments, pigs were allowed to adjust to dietary treatment for 14 d and then imaged on d 14 through 20. Addi-

tionally, pigs were weighed and feeder weights were collected on d 14 and 21 to determine average daily gain, feed disappearance, and feed utilization.

Data from Exp. 2 were analyzed in a randomized complete block design. Pigs were blocked by initial weight and were the experimental unit. Initial BW was used as a covariate to control for the effects of different BW changes by treatment during the 2-week adaptation period. Linear and quadratic polynomials were used to determine the effects of increasing dietary energy content on growth performance, MBST, and MBSL.

Results and Discussion

Experiment 1. Linear and quadratic effects were observed for ADG, ADFI, and G/F ($P<0.01$; Table 2). These effects resulted from the increased growth performance and feed intake observed as calculated daily ME intake increased from 0.75 × MEm to ad libitum consumption. A treatment × time interaction was observed for MBST ($P<0.01$; Figure 1). This interaction resulted from treatment effects differing by time period. The MBST increased as daily ME intakes increased (linear, $P<0.05$) at 0700 and 1900. At 1100 h, MBST was lowest for pigs fed 0.75 × MEm versus those fed the other three treatments (quadratic, $P<0.05$).

Consistent with previous research, our results showed that as the pig increases its growth rate and feed intake, heat production associated with increased digestion and growth processes increases the body temperature and the heat loss to the surrounding environment.

Experiment 2. Increasing dietary energy density from 1,250 kcal ME/lb to 1,590 kcal ME/lb improved ADG (linear, $P<0.01$; Table 3) and G/F (linear, $P<0.05$) and tended to affect ADFI (quadratic, $P<0.08$). Average daily feed intake was lowest for pigs fed 1,250 kcal ME/lb and highest for the pigs fed 1,475 kcal ME/lb. Calculated ME intake per day also increased as dietary energy density increased (linear, $P<0.01$). Additionally, MBST and MBSL increased as dietary energy density increased from 1,250 kcal ME/lb to 1,590 kcal ME/lb (linear, $P<0.01$).

Increasing dietary energy density increased MBST and MBSL, similar to our results in Exp. 1, where increased daily feed allowance of a common diet increased MBST and MBSL. The growth performance results are consistent with previous research evaluating the effects of altering feed intake or dietary nutrient profile on the growth performance of growing pigs.

Our results in Exp. 2 further indicate that high-fiber, low-energy diets reduce feed intake and growth performance, but that the pig will adjust its daily feed intake to compensate for more moderate differences in dietary energy content. This regulation of feed intake relative to dietary energy density is apparent by the increased feed intake of the pigs fed 1,360 kcal ME/lb versus pigs fed 1,475 or 1,590 kcal ME/lb diets. Additionally, pigs fed the 1,590 kcal ME/lb diet did not reduce their feed intake as dietary energy increased above 1,475 kcal ME/lb diet. Thus, the higher energy supported higher ADG, leading to a higher G/F in comparison to pigs fed lower energy diets.

Our results suggest that infrared thermography can be used to detect differences in MBST and MBSL of individual pigs associated with feed intake, growth rate, and dietary energy content in more variable environmental conditions than those found with traditional calorimetry chambers. The ability of infrared thermography to detect differences in environments that are not closely controlled indicates that further development of this technology for use in more traditional growth assays, growth modeling, and commercial production situations is possible. Additional infrared thermography applications in swine research and production may allow direct estimates of changes in swine thermoenergetics due to the effects of treatment or environment.

Table 1. Compositions of Diets[a]

		Experiment 2, kcal ME/lb of diet			
Ingredients, %	Exp. 1	1,250	1,360	1,475	1,590
Corn	64.46	32.74	50.20	62.23	56.41
Soybean meal, 46.5% CP	32.53	21.39	26.85	31.59	35.41
Soybean oil	---	---	---	---	5.20
Alfalfa meal	---	30.94	18.10	3.30	---
Wheat middlings	---	13.20	2.50	---	---
Monocalcium phosphate	1.17	0.99	1.21	1.19	1.18
Limestone	1.10	---	0.40	0.95	1.05
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin premix[b]	0.20	0.20	0.20	0.20	0.20
Trace mineral premix[c]	0.15	0.15	0.15	0.15	0.15
Medication[d]	0.05	0.05	0.05	0.05	0.05
Diet Composition,					
Crude Protein, %					
Calculated	20.48	20.02	20.13	20.41	21.15
Analyzed	21.38	22.51	22.87	23.58	23.67

[a]All diets were formulated to contain 0.75% Ca and 0.65% P.
[d]Provided 25 mg tylosin per lb of complete diet.

Table 2. Effects of Feed Intake Regimen on Growth Performance of 55 lb Pigs (Exp. 1)[a]

	Feed Intake Level[b]				
Item	0.75 × MEm	1.5 × MEm	2.5 × MEm	Ad Libitum	SEM
ADG, lb[cd]	-0.02	1.41	1.96	2.58	0.09
ADFI, lb[cd]	1.04	1.90	2.98	3.62	0.09
G/F[cd]	-0.03	0.75	0.67	0.70	0.04

[a]Eighty pigs (initially 55 ± 6 lb) were blocked by initial weight and allotted in a randomized complete block design. Results are the means of a 5 d growth assay.
[b]Metabolizable energy per day for maintenance calculated as 106*kg $BW^{.75}$.
[c]Linear treatment effect (P<0.01).
[d]Quadratic treatment effect (P<0.01).

Table 3. Effects of Dietary Energy Regimen on Growth Performance, Mean Body Surface Temperature, and Mean Body Surface Radiant Heat Loss of 130 lb Pigs (Exp. 3)[a]

	Dietary Energy, ME/lb[b]					Probability (P<)	
Item	1,250	1,360	1,475	1,590	SEM	Linear	Quad.
ADG, lb	2.36	2.51	2.73	2.82	0.13	0.01	0.76
ADFI, lb	6.44	7.25	6.86	6.90	0.22	0.31	0.08
G/F	0.37	0.35	0.39	0.41	0.02	0.05	0.39
Calculated ME intake, Mcal/d	8.03	9.88	10.10	10.96	0.33	0.01	0.12
MBST, F[c]	89.8	90.5	90.7	91.0	0.29	0.01	0.33
MBSL, kcal/h[c]	-67.2	-70.7	-73.0	-74.8	1.10	0.01	0.34

[a]Eighty pigs (initially 130 ± 11 lb) were blocked by initial weight and allotted in a randomized complete block design.
[b]Calculated values from the NRC (1998) were used for dietary ME content.
[c]Initial BW was used as a covariate in this analysis.

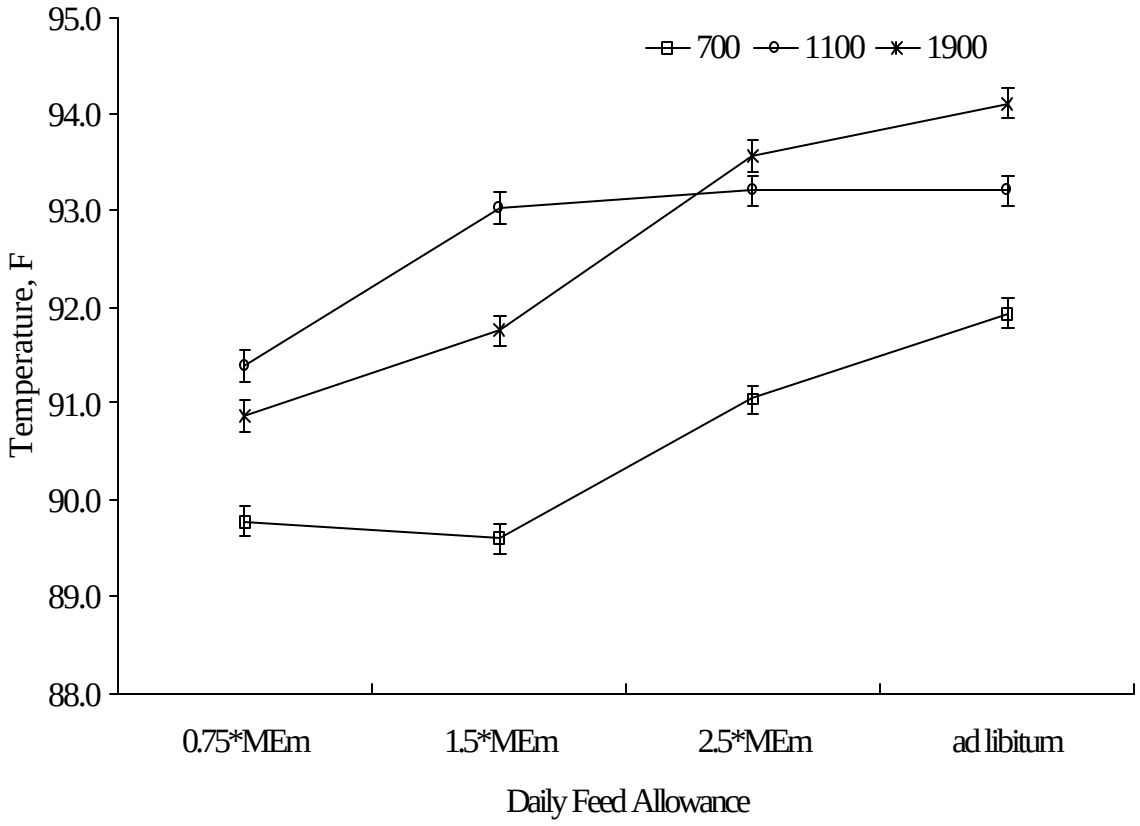


Figure 1. Effects of Daily Feed Allowance on Mean Body Surface Temperature of 55 lb Pigs. Restricted-fed pigs were fed at 0730 daily.

AIR QUALITY IN SWINE-FINISHING BARNS[1]

B. Z. Predicala[2], R. G. Maghirang[2], R .D. Goodband, S. B. Jerez[2], and J.E. Urban[3]

Summary

Air quality was assessed in two commercial swine-finishing barns: one naturally ventilated (NV) and one mechanically ventilated (MV). The concentrations of inhalable dust (IDC), respirable dust (RDC), airborne viable particles, carbon dioxide (CO_2), and ammonia (NH_3), as well as the air temperature and relative humidity (RH) inside the barns were monitored for 41 weeks. The two barns did not differ significantly ($P>0.05$) in IDC, RDC, and bioaerosol concentration. Overall mean levels for IDC, RDC, CO_2, and NH_3 were below the threshold limit values specified by the American Conference of Governmental Industrial Hygienists (ACGIH). However, some measurements exceeded the exposure limits suggested by previous researchers, especially during cold days. In general, the air quality in the two types of buildings was acceptable except under certain conditions (e.g., low ventilation rates during cold weather). In such case, workers and producers may need help or further training to ensure adequate air quality. In addition, under these conditions, workers should wear respiratory protective devices to minimize risk of inhalation of dust, gases, and bioaerosols.

(Key Words: Indoor Air Quality, Livestock Buildings, Airborne Contaminants.)

Introduction

In recent years, some livestock operations have become potentially hazardous to the workers and producers because of poor air quality, excessive noise levels, substandard lighting, and physical interaction of workers with animals. A growing body of literature has documented the health problems among workers in some of these operations. A survey of swine confinement workers, for example, reported the following statistics:

- at least 60% of workers surveyed had acute or subacute respiratory symptoms, including dry cough, chest tightness, and wheezing on exposure to the work environment; irritation of the nose, eyes, and throat; and stuffy nose and head.
- at least 25% of workers surveyed had periodic, acute, febrile episodes with fever, headache, muscle aches and pains, chest tightness, and cough.
- at least 25% of workers surveyed experienced chronic bronchitis, occupational (nonallergic) asthma, and noninfectious chronic sinusitis.

In addition, data from the University of Iowa have led to the following suggested exposure limits for swine confinement workers: 2.4 mg/cu m total dust, 0.23 mg/cu m respirable dust, 1500 ppm carbon dioxide (CO_2), and 7 ppm ammonia (NH_3). These limits are con-

[1]Supported by the Agricultural Experiment Station, KSU Special Group Incentive Research Awards Program, and Kansas Center for Agricultural Resources and Environment. The authors thank the swine producer and Darrell Oard, Kim Ocfemia, and Michelle Peterie for technical assistance.

[2]Department of Biological and Agricultural Engineering.

[3]Division of Biology.

siderably lower than the threshold limit values (TLVs) specified by the American Conference of Governmental Industrial Hygienists (ACGIH) for industrial occupational settings, largely because of the high biological activity of the dust and the additive or synergistic reactions of the combined mixture of dust and gases in livestock buildings. Clearly, air quality in livestock confinement facilities should be controlled to prevent occupational health problems.

The main objective of the study was to assess the air quality in swine growing-finishing houses. The specific objectives were to:

- determine the concentrations of inhalable dust (IDC), respirable dust (RDC), carbon dioxide (CO_2), ammonia (NH_3), and total and respirable viable airborne microorganisms, and
- compare a naturally ventilated barn and a mechanically ventilated barn in terms of the above air quality parameters.

Procedures

The air quality in two barns for growing-finishing pigs was evaluated by measuring the IDC, RDC, airborne viable particles, CO_2, and NH_3. Sampling was done weekly for a 24 to 48 hr period for 41 weeks from July 1999 to May 2000.

The barns, one naturally ventilated (NV) and one mechanically ventilated (MV), were located on the same commercial swine farm in northeast Kansas. The choice of two test barns on a single farm ensured that the overall conditions, including outdoor environmental conditions, breed of pigs, type of feeds and supplements, feeding system, veterinary support, and husbandry practices, were similar (Table 1).

In the NV barn, air sampling was done in a room with 11 pens. In the MV barn, sampling was performed in a room with 10 pens on each side of the alley. The mean stocking densities were 0.68 and 0.65 sq m/head in the NV and MV barns, respectively. The pigs were brought into the barns when they weighed about 25 to 35 kg each and remained in the barns for about 15 to 17 weeks.

The RDC was measured with a respirable dust cyclone, which had a cut-point diameter of 4 mm at 2.2 l/min airflow rate. The IDC was measured with an IOM (Institute for Occupational Medicine) sampler at an airflow rate of 2.0 l/min. Three samplers of each type were installed in each barn. These were located at heights of 1.5 m above the floor over two pens and 1.75 m above the floor along the central alley. Flow meters and critical orifices were used to maintain the sampling airflow rate to within ±5% of the desired rate. Before and after sampling, the samplers including the collection filters were preconditioned in a container with constant humidity and temperature for 24 h before weighing to minimize the effect of humidity on the weights of the filters.

Bioaerosol sampling involved collection of airborne particulates on cellulose nitrate membrane filters and incubation for 72 hr at room temperature on plates with R2A agar as a culture medium. An open-faced filter holder loaded with a 47-mm membrane filter and a respirable dust cyclone with a 37-mm filter were used for sampling total viable particles and respirable viable particles, respectively. Sampling was done at an airflow rate of 2.0 l/min for 3 min. After incubation, the colony-forming units (CFUs) were counted. The colonies on each plate also were categorized based on appearance, i.e., color, surface form, size, and surface texture, and then identified by standard microbiological techniques.

Carbon dioxide concentration, NH_3 concentration, air temperature, and relative humidity (RH) were measured near the dust-sampling location along the alley. In the NV barn, CO_2 and NH_3 concentrations as well as the temperature were recorded every 30 minutes. The CO_2 concentration was monitored with a nondispersive infrared analyzer. The NH_3 concentration was measured with an NH_3 monitor. Temperature was monitored at each sampling point with type T thermocouples. In the MV barn, CO_2 and NH_3

concentrations were measured with detector tubes at the start and the end of each sampling period. The RH was determined in both barns with a direct reading thermo-hygrometer.

Results and Discussion

The ranges of air temperatures and RHs inside the two NV barns are shown in Table 1. The mean air temperature and RH were 21.5°C and 42%, respectively, in the NV barn and 24.2°C and 43%, respectively, in the MV barn. The air temperatures and RHs outside the barns were obtained from the nearest weather station about 20 km away. The outside air temperatures for the duration of the study ranged from –3.9 to 31.9°C with a mean of 13.5° C; the outside relative humidities ranged from negligible (<1%) during extremely cold days to 83 % with a mean of 33 %.

The overall IDC and RDC in the NV barn were 2.19 mg/m^3 and 0.10 mg/m^3, respectively. These were not significantly ($P>0.05$) different from the corresponding values obtained in the MV barn, which were 2.13 mg/cu m and 0.11 mg/cu m, respectively. Within the NV barn, the combined mean IDC for the two pens (2.15 mg/cu m) was not significantly ($P>0.05$) different from the mean IDC along the alley (2.26 mg/cu m) (Table 2). Similarly, no significant ($P>0.05$) difference was observed in the MV barn; mean IDCs were 2.16 mg/cu m and 2.08 mg/cu m for the pens and the alley, respectively.

The RDCs were lower than the TLV of 3.0 mg/cu m for respirable particulates specified by ACGIH; however, they exceeded the recommended exposure limit of 0.23 mg/cu m for RDC for one of 30 measurements in the NV barn and for three of 36 measurements in the MV barn. The IDCs were also lower than the TLV of 10 mg/cu m for total dust specified by ACGIH. They were higher than the recommended exposure limit of 2.4 mg/cu m for nine of 30 measurements in the NV barn and for 11 of 36 measurements in the MV barn. In general, the measured values exceeded the corresponding recommended exposure limits during the period between November and March, when the outside air temperature was about 12°C or less. During this period, both curtains in the NV barn were closed most of the time to conserve heat. In the MV barn, one inlet was closed either partially or totally and most of the time, only one exhaust fan was operated at short intervals. The ventilation rate was lower during this period compared to the warm months (April to October); consequently, the airborne dust concentrations were high.

The measured RDC values (0.10 and 0.11 mg/cu m) were lower than those reported in the literature for growing-finishing swine houses. Mean RDCs of 0.18 and 0.19 mg/cu m in naturally and fan-ventilated barns, respectively, were reported in one study. Another study observed a mean RDC of 0.92 mg/cu m in four finishing barns in Iowa, although their measurements were taken during cold months only. The measured IDCs were also lower or comparable to those in a number of studies. In one study in Iowa, mean total dust concentration was 15.3 mg/cu m (SD = 1.4) in four barns during cold months, whereas a survey of farms in northern Europe showed a mean IDC of 2.19 mg/cu m (range = 1.87 to 2.76 mg/cu m).

The mean concentration of total CFUs inside the NV barn (6.0×10^4 CFU/cu m) was not significantly ($P>0.05$) different from that in the MV barn (1.7×10^4 CFU/cu m) (Table 3). Both values were significantly ($P<0.05$) higher than the corresponding mean concentrations outside each barn (NV = 1.7×10^4, MV = 2.0×10^4 CFU/cu m). The two barns also did not show any significant ($P>0.05$) difference in mean concentrations of the viable respirable particles (NV = 9.8×10^3, MV = 1.0×10^4 CFU/cu m). These values were about 2 to 3 times higher than the corresponding concentrations outside the barns (NV = 4.5×10^3, MV = 3.8×10^3 CFU/cu m). The above values were within the range of published CFU concentrations. A survey of 28 swine confinement units in Iowa showed a mean of 1.4×10^6 CFU/cu m for total viable microorganisms. Another study observed means of 4.2×10^5 CFU/cu

m and 1.6×10^5 CFU/cu m for the total and respirable bioaerosol concentrations, respectively.

Preliminary identification of the persistent strains of microorganisms indicated that the viable particles could be various species of the following genera: *Pseudomonas, Staphylococcus, Listeria, Escherichia, Klebsiella, Citrobacter, Lactobacillus, Sarcina,* and *Penicillium*. The relative abundance of these species changed with time. Further identification of the microorganisms is being pursued, particularly for the genera with species known to be potentially pathogenic to humans and animals.

The CO_2 concentrations ranged from 378 to 2095 ppm with a mean of 1106 ppm (SD = 421 ppm) in the NV barn and from 550 to 2225 ppm with a mean of 1417 ppm (SD = 538 ppm) in the MV barn. All measured values were below the TLV of 5000 ppm set by ACGIH. However, they exceeded the 1500 ppm CO_2 maximum level recommended by previous researchers in four out of 21 measurements in the NV barn and 13 out of 26 measurements in the MV barn .

The NH_3 concentrations in the NV barn ranged from negligible (<1 ppm) during extremely windy days to 17.1 ppm during cold days when the side curtains were closed; the overall mean was 6.6 ppm (SD = 4.4 ppm). In the MV barn, they ranged from 5.2 to 24.7 ppm with a mean of 11.9 ppm (SD = 5.9 ppm). The measured NH_3 levels were below the TLV of 25 ppm set by ACGIH; however, they exceeded the recommended NH_3 exposure limit of 7 ppm for humans seven times in the NV barn and 13 times in the MV barn out of 19 measurements in both barns. For both CO_2 and NH_3, the measured values exceeded the proposed exposure limits during approximately the same period that the exposure limit for inhalable dust was exceeded.

The measured CO_2 and NH_3 concentrations were comparable to published values for swine confinement units. One study reported means of 9 ppm for NH_3 (SD = 5.2, range = 3.3 to 25 ppm) and 1740 ppm for CO_2 (SD = 851, range = 900 to 4500 ppm) from 28 swine barns in Iowa. A survey of 15 fattening barns in northern Europe showed CO_2 concentrations ranging from 455 to 2355 ppm with a mean of 1400 ppm (SD = 703). Mean NH_3 concentrations in those ranged from 12.1 to 18.2 ppm with an overall mean of 14.8 ppm.

The observations and the results of this study indicate that for these two specific barns and perhaps in others with similar design features, implementing a combination of measures in relation to manure management, proper ventilation, and controlling feed dust and manure gas might help improve the overall air quality. Because feed is one of the main dust sources, the use of pelleted feeds and/or covered feeder chutes could reduce the generation and concentration of dust. Thorough cleaning and sanitation of all surfaces in the barns and more frequent flushing of the manure pits could reduce the overall dustiness and the levels of gases inside the barns. The ventilation system and its components should be maintained properly to ensure adequate ventilation rates, especially during cold weather. Workers can be protected from exposure to the air contaminants with masks or respirators approved by the National Institute for Occupational Safety and Health.

Table 1. Description of the Two Commercial Swine-Finishing Barns

Features	Naturally Ventilated, NV	Mechanically Ventilated, MV
Overall dimensions, m	12 × 140	9.8 × 54
Breed of pigs	PIC Line 327 × C22 (Pig Improvement Co., Franklin, KY)	PIC Line 327 × C22 (Pig Improvement Co., Franklin, KY)
Number of rooms	5	2
Capacity per room, head	300 – 320	320 - 340
Waste system	Shallow pit, flushed twice weekly	Deep static pit, overflow drained continuously
Type of feed/Feeding system	Ground feed, Automatic self-feeders, Overhead auger delivery	Ground feed, Automatic self-feeders, Overhead auger delivery
Watering system/Location	Suckling waterer, Separate from feeder	Suckling waterer, Integrated with feeder
Environmental control	Automatic curtains, Manual ridge slot adjustment, Misting system	Automatic fan On/Off, Manual inlet slot adjustment, Misting system, Pit ventilation
Room air temperature, °C	14.2 - 33.1	17.8 - 34.3
Room RH, %	22 - 72	27 - 68

Table 2. Mean Concentrations (mg/cu m) of Inhalable and Respirable Dust in Two Swine-Finishing Barns

Dust	Sampling	Naturally Ventilated Barn			Mechanically Ventilated Barn		
Fraction	Location	Mean[a]	SD	Range	Mean[b]	SD	Range
Inhalable	Pen 1	1.91	1.50	0.15 - 5.86	2.11	1.40	0.22 – 7.20
	Alley	2.26	1.87	0.14 - 7.34	2.08	1.54	0.15 - 7.43
	Pen 2	2.39	1.66	0.41 - 5.81	2.22	1.75	0.08 - 8.37
Respirable	Pen 1	0.10	0.07	0.03 - 0.34	0.11	0.06	0.03 - 0.34
	Alley	0.10	0.07	0.01 - 0.30	0.10	0.06	0.01 - 0.30
	Pen 2	0.10	0.06	0.01 - 0.28	0.12	0.08	0.01 - 0.44

[a]Number of observations = 30.
[b]Number of observations = 36.

Table 3. Mean Concentrations of Viable Particles (CFU/cu m) in Two Swine-Finishing Barns

	Sampler	Naturally Ventilated Barn			Mechanically Ventilated Barn		
Location	Type	Mean[a]	SD	Range	Mean[a]	SD	Range
Inside	Total	6.0×10^4 (30)	5.6×10^4	1.2×10^2 - 2.4×10^5	6.7×10^4 (36)	3.7×10^4	1.3×10^4 - 1.4×10^5
	Respirable	9.8×10^3 (28)	9.9×10^3	5.0×10^2 - 4.5×10^4	1.0×10^4 (36)	1.1×10^4	1.6×10^3 - 6.4×10^4
Outside	Total	1.7×10^4 (26)	1.5×10^4	3.7×103 - 6.3×10^4	2.0×10^4 (34)	1.8×10^4	3.7×10^3 - 8.0×10^4
	Respirable	4.5×10^3 (26)	4.2×10^3	1.7×10^2 - 1.8×10^4	3.8×10^3 (33)	4.8×10^3	5.0×10^2 - 2.8×10^4

[a]Numbers of observations are shown in parentheses.

EFFECTS OF pH AND LOCATION WITHIN A LOIN ON PORK QUALITY

B. S. Andrews, J. A. Unruh, M. C. Hunt, and C. L. Kastner

Summary

Eighty-one boneless pork loins were used to determine the influence of pH on quality characteristics. With increasing loin pH, instrumental values for L* (lightness) and b* (yellowness) of loins and chops decreased, and cooking losses of chops before 0 d and after 1 d of retail display also decreased. The pH had no effects on package losses or Warner-Bratzler shear force values of chops. Center loin chops (0 d and 1 d) had higher ratios of reflectance than blade and sirloin chops. Sirloin chops had higher ratio of reflectance than blade chops. Center loin chops had lower package losses than blade and sirloin chops. Blade chops had lower (more tender) WBS values than center loin and sirloin chops. Measuring loin pH can predict instrumental color (L*and b*) values as well as cooking losses.

(Key Words: Pork Chops, pH, Quality.)

Introduction

Meat color is one of the most important visual characteristic sought by consumers as an indicator of a freshness and wholesomeness. It has been stated that the extent of a meat product's shelf life depends on its quality characteristics, mainly color. Products with adequate color will give the appearance of an acceptable product, thus leading to faster retail sales. In addition to color, another major quality characteristic is the amount of moisture loss during fabricating, packaging, and processing. Meat is sold on a weight basis, so it is essential to select products that have a high water-holding capacity and will maintain a constant weight through various processes. Meat color and water-holding capacity often are related to ultimate pH of meat and quite often are utilized by packers as indicators of muscle quality in pork. Therefore, it is essential to have an understanding of the relationship between muscle color and water-holding capacity and meat pH.

Procedures

Eighty-one boneless pork loins were obtained from a commercial packing facility utilizing pH as a selection criterion. A pH probe designed specifically for Farmland Industries (Cypress, Lawrence, KS) was inserted on the bone side, 10 in. from the anterior end of the pork loin. Spectral data for the ratio of reflectance %R630/%R580 and CIE Lab color readings were taken over the bone surface at the blade (6 -7th rib), center (last rib), and sirloin (5-6th lumbar) locations using a HunterLab Miniscan (Hunter and Associates, Reston, VA.) with a 10° observer and Illuminate C. Loins were then placed into vacuum bags (CRYOVAC, Duncan, SC) and vacuum packaged (Target 4 Torr, Model 14EL, CRYOVAC). After packaging, loins were passed through a shrink tunnel (198° to 202°F) and aged for 14 d at 31°F in Farmland's warehouse. Loins then were transported to Kansas State University, where they were stored for 30 d at 31°F. At 44-d postmortem, loins were weighed, removed from the vacuum bags, and were allowed to bloom for 15 min at 32°F prior to cutting into 1-in. chops.

Chops at 4, 11, and 19 in., anterior to posterior, were used to determine Warner-Bratzler shear (WBS) force; package, cooking, and total moisture losses; and instrumental color. These locations represent the blade, center, and sirloin sections of a loin. Shear-force chops were weighed, covered with polyvinyl chloride (PVC) wrap in 2S Styrofoam trays, and weighed again. Spectral data for the

ratio of reflectance %R630/% R580 and CIE Lab color readings were taken immediately (0 d) taken on each chop before being placed into an open-top retail display case for 24 h at 32°F under continuous 1614 lux lighting from Phillips Deluxe Warm White fluorescent lights (40 watt). Each chop was scanned at two locations (lateral and medial), and values were averaged. After 24 h, instrumental color readings (1 d) were taken, and each chop was weighed.

Shear-force chops were cooked to an internal temperature of 160°F in a Blogdett dual-air-flow oven (DFG-201, G.S., Blodgett Co., Inc., Burlington, VT). Temperature was monitored using thermocouples attached to a Doric Minitrend 205 temperature recorder (Emmerson Electric S.A., Doric Div., San Diego, CA). Chops then were cooled at room temperature for 1 h and weighed. They were chilled 24 h at 38°F before six 0.5-in. cores were taken parallel to the muscle fibers and sheared perpendicular to the muscle fibers using a WBS attachment connected to an Universal Instron testing machine (Model 4201, Instron, Canton, MA). Package and cooking losses were calculated by the equations [(initial wt.-aged wt.)/initial wt.] and [(raw wt. -cooked wt.)/raw wt.], respectively. Total moisture loss was calculated by the equation [1-((1-purge, %) × (1- package loss, %) × (1-cooking loss, %))].

Results and Discussion

No differences (P>.05) were observed in plant measurements for CIE a* (measures of redness) or ratio of reflectance values (Table 1). Chops CIE L* values decreased (became darker) with increased loin pH. Chops at lower pH (<5.5) had higher (P<.05) L* values (lighter in color) than chops with intermediate pHs (5.6 to 5.9) and high pHs (6.0 to >6.2). However, chops with intermediate pH had higher (P<.05) L* values than chops with high pH. In addition, values for CIE b* (an indicator of yellowness) decreased with increased loin pH. Chops with low pHs (<5.5 and 5.6) had higher (P<.05) b* values than chops with a higher pHs (5.8 to >6.2). The differences in b* values became less with increased loin pH.

Quality characteristics of shear-force chops are reported as pH means in Table 1. Similar to plant measurements, CIE L* and b* values of shear-force (0 d) chops decreased with increased loin pH. Chops with a pH of <5.5 had higher (P<.05) L* values than chops with pHs of 5.7 to >6.2. However, chops with a pH of 5.7 had higher (P<.05) L* values than chops with a pH of >6.2. Moreover, chops with a pH of 5.5 had higher (P<.05) b* values than chops with pHs of 5.8 to >6.2. However, chops with a pH of 5.8 had higher (P<.05) b* values than chops with a pH of >6.2. The ratio of reflectance (measures oxymyoglobin content) seemed to increased with increasing loin pH. Chops with a pH of 5.5 had a lower (P<.05) ratio of reflectance than chops with a pH of 6.1.

After 24 h storage (1 d) in an open-top retail display case, CIE Lab color reading were taken on shear force chops and presented as pH means (Table 1). Similar to 0-d color readings, 1-d L* values decreased with increased loin pH. Chops with low pHs (<5.5 and 5.5) had higher (P<.05) L* values than chops with higher pHs (5.7 to >6.2). However, chops with pHs of 5.7 to 5.9 had higher (P<.05) L* values than chops with a pH of >6.2. No general trend was observed between pH and a* values. However, chops with a pH of <5.5 had lower (P< .05) a* values (less red) than chops with higher pHs (6.0 to >6.2). Chops with pH of 5.5 had lower (P<.05) a* values than chops with pH of 5.8. In addition, b* values decreased with increased loin pH. Chops with lower pHs (<5.5 and 5.5) had higher (P<.05) b* values (more yellow) than chops with higher pHs (6.0 to >6.2). Moreover, chops with a pH of 5.8 had higher (P<.05) b* values than chops with a pH of >6.2.

A more apparent trend for the ratio of reflectance was observed on shear-force chops after 24 h of display. Chops with a pH of <5.5 had the lowest ratio of reflectance, and the ratio increased with increasing loin pH. Chops with pH of <5.5 had a lower (P<.05) ratio of reflectance than chops with pHs of 5.7 to >6.2. However, chops with a pH of 5.7 had a lower (P<.05) ratio of reflectance than chops with pHs of 6.0 and 6.1.

Cookery characteristics of shear-force chops are reported as pH means in Table 1.

No differences (P>.05) were observed for WBS and percentage of package losses. However, differences (P<.05) in cooking losses were observed. Chops with low pH (<5.5) had the highest cooking losses, and losses decreased with increased loin pH. Shear force chops with lower pHs (<5.5 and 5.5) had higher (P<.05) cooking losses than chops with higher pHs (5.8 to >6.2). However, chops with a pH of 5.8 had higher (P<.05) cooking losses than chops with a pH of >6.2.

Plant instrumental color values by location within the loin are shown in Table 2. No differences (P>.05) were observed for CIE a* or ratio of reflectance values. The center loin section had higher (P<.05) L* values than the blade or sirloin sections. The blade section had a higher (P<.05) b* value than the center loin section.

Quality differences (P<.05) were found by location for shear force chops stored in an open-top retail case for 0 d and 1 d (Table 2). Blade chops had higher (P<.05) 0-d and 1-d L* values than center loin and sirloin chops. However, sirloin chops had higher (P<.05) 0-d and 1-d L* values than the center loin chops. Center loin chops had higher (P<.05) 0-d and 1-d a* values than blade and sirloin chops. Blade chops had higher (P<.05) 0-d and 1-d b* values than the center loin and sirloin chops. In addition, center loin chops had higher (P<.05) 0-d ratio of reflectance than blade and sirloin chops. However, center loin chops had a higher (P<.05) 1-d ratio of reflectance than blade and sirloin chops. In addition, sirloin chops had a higher (P<.05) ratio of reflectance than blade chops.

Cookery traits and WBS values are represented as location means and shown on Table 2. No differences (P>.05) were found for cooking losses. However, center loin chops had lower (P<.05) package losses than chops from than blade and sirloin regions. Blade chops had lower (P<.05; more tender) WBS values than center and sirloin chops.

This study suggests that pork quality characteristics vary with pH and chop location within a loin. Therefore, muscle pH can be a useful predictor of pork loin quality to produce a consistent product for consumers.

Table 1. Influence of Loin pH on Instrumental Color, Warner-Bratzler Shear Force, and Cookery Traits

	Loin pH									
Variables	<5.5	5.5	5.6	5.7	5.8	5.9	6.0	6.1	>6.2	SE
Plant Instrumental Color[x]										
L*	57.25^{d}	55.01^{cd}	54.37^{c}	53.16^{bc}	51.05^{ab}	52.77^{bc}	49.99^{a}	49.35^{a}	49.05^{a}	0.783
a*	8.53	7.33	7.34	8.04	7.85	6.67	7.10	7.25	7.11	0.535
b*	14.04^{d}	13.26^{cd}	13.10^{cd}	13.01^{bcd}	12.22^{ab}	11.70^{ab}	11.64^{a}	11.47^{a}	11.05^{a}	0.540
% R630/% R580	2.49	2.40	2.38	2.52	2.46	2.41	2.56	2.55	2.61	0.075
Shear Force Chop Color 0 d[y]										
L*	62.35^{d}	61.90^{d}	59.17^{cd}	57.11^{bc}	56.67^{bc}	56.13^{bc}	54.48^{ab}	54.13^{ab}	52.77^{a}	1.140
a*	12.11	11.43	13.03	12.77	12.06	11.51	11.42	12.21	11.27	0.882
b*	19.33^{de}	19.60^{e}	18.89^{cde}	18.68^{cde}	18.38^{bcd}	17.82^{abc}	17.35^{ab}	17.41^{ab}	17.21^{a}	0.376
% R630/% R580	2.66^{ab}	2.58^{a}	2.89^{abc}	3.01^{bc}	2.87^{abc}	2.90^{abc}	2.99^{abc}	3.13^{c}	2.97^{ab}	0.151
Shear Force Chop Color 1 d[z]										
L*	61.95^{e}	61.27^{e}	59.39^{de}	56.98^{cd}	55.65^{bc}	55.77^{bc}	53.75^{ab}	53.57^{ab}	52.38^{a}	1.000
a*	10.13^{a}	10.88^{ab}	11.80^{bc}	11.47^{abc}	12.78^{c}	11.65^{abc}	12.11^{bc}	12.38^{bc}	11.90^{bc}	0.527
b*	19.38^{cd}	19.47^{cd}	19.57^{d}	18.88^{abcd}	19.22^{bcd}	18.50^{abc}	18.37^{ab}	18.26^{ab}	17.99^{a}	0.337
% R630/% R580	2.38^{a}	2.51^{ab}	2.67^{abc}	2.75^{bcd}	2.98^{cde}	2.93^{cde}	3.13^{e}	3.21^{e}	3.07^{de}	0.337
Cookery Traits										
Package loss, %	4.16	4.05	3.96	4.20	3.82	3.92	3.92	4.00	4.12	0.324
Cooking loss, %	25.53^{d}	25.21^{d}	23.89^{cd}	23.50^{cd}	21.88^{bc}	20.03^{ab}	19.98^{ab}	19.03^{ab}	18.31^{a}	1.086
WBS, kg	3.09	3.21	2.69	2.09	2.56	2.39	3.04	2.68	2.75	0.417

[a,b,c,d,e]Means within a row with different superscript letter differ (P<.05).

[x]Lightness (L*), redness (a*), yellowness (b*), or indicator of the amount of oxymoglobin present (ratio of reflectance % R630/ % R580) measured on the loins in the packing plant.

[y]Instrumental color measurement taken on shear-force chops prior to storage in an open-top retail display case.

[z]Instrumental color measurements taken on shear-force chops after 24 h storage in an open-top retail display case.

Table 2. Influence of Loin Location on Quality Characteristics

	Location			
Variable	Blade	Center	Sirloin	SE
Plant Instrumental Color[x]				
L*	52.83	51.50[a]	53.00[b]	0.574
a*	7.49	7.33	7.60	0.314
b*	12.71[b]	12.00[a]	12.45[ab]	0.363
% R630/% R580	2.51	2.49	2.47	0.053
Instrumental Color 0 d[y]				
L*	59.52[c]	54.47[a]	57.57[b]	0.574
a*	11.61[a]	12.74[b]	11.59[a]	0.646
b*	18.63[b]	18.08[a]	18.18[a]	0.177
% R630/% R580	2.76[a]	3.09[b]	2.81[a]	0.076
Instrumental Color 1 d[z]				
L*	58.99[c]	54.21[a]	57.04[b]	0.548
a*	11.29[a]	12.47[b]	11.27[a]	0.213
b*	19.14[b]	18.60[a]	18.82[a]	0.135
% R 630/% R580	2.71[a]	3.04[c]	2.80[b]	0.135
Cookery Traits				
Package loss, %	4.23[b]	3.72[a]	4.1[b]	0.294
Cooking loss, %	22.62	21.91	21.35	0.698
WBS, kg	2.42[a]	2.88[b]	2.87[b]	0.168

[a,b,c]Means within a row with different superscript letter differ (P<.05).

[x]Lightness (L*), redness (a*), yellowness (b*), or indicator of the amount of oxymoglobin persent (ratio of reflectance %R 630/% R580) measured at the packing plant.

[y]Initial color measurement taken on shear-force chops prior to storage in an open-top retail display case.

[z]Color measurements taken on shear-force chops after 24 h storage in an open-top retail display case.

EFFECTS OF FREEZING PORK CHOPS ON WARNER-BRATZLER SHEAR FORCE AND COOKERY TRAITS

B. S. Andrews, J. A. Unruh, M. C. Hunt, and C. L. Kastner

Summary

Eighty-one boneless pork loins were used to determine the influence of freezing and pH on Warner-Bratzler shear force (WBS) values and cookery traits. Chops with lower pH (<5.5 to 5.5) had higher cooking losses than chops with intermediate pH (5.7 to 5.9) and higher pH (6.0 to >6.2). Similar to cooking losses, total moisture losses decreased with increased pH. Frozen chops had lower WBS values (more tender) than fresh chops. However, fresh chops had a higher total yield (lower moisture loss) than frozen chops.

(Key Words: Pork, Quality, Freezing.)

Introduction

One of the many concerns of the meat industry is extending shelf life of a product for prolonged shipment or storage. More than 80% of fresh pork produced in the U.S. is shipped overseas, and this prolonged storage has the potential of causing spoilage, making the product unsaleable. Therefore, an effective method to preserve quality characteristics is needed. Freezing pork loins can be an alternative to sending a fresh product. Freezing has been shown to prevent microbial growth. In addition, freezing temperature for the correct amount of time also can destroy *Trichinella spiralis*, a major parasite found in pork. However, freezing of pork may have adverse effects on tenderness and moisture loss.

Procedures

Eighty-one boneless pork loins were obtained from a commercial packing facility utilizing pH as the selection criterion. A pH probe designed specifically for Farmland Industries (Cypress, Lawrence, KS) was inserted on the bone side, 10 in. from the anterior end of the pork loin. Loins were placed into vacuum bags (CRYOVAC, Duncan, SC) and vacuum packaged (Target 4 Torr, Model 14EL, CRYOVAC, Duncan, SC). After packaging, loins were run through a shrink tunnel (198° to 202°F) and aged for 14 d at 31°F in Farmland's warehouse. Loins then were transported to Kansas State University, where they were stored for 30 d at 31°F. At 44-d postmortem, loins were weighed, removed from the vacuum bags, and cut into 1-in. chops.

Chops at 10 and 11 in., anterior to posterior, were used to determine package, cooking, and total percentage moisture losses as well as Warner-Bratzler shear force values (WBS). Chops taken at 10 in. were vacuum packaged (CRYOVAC, Duncan, SC); frozen; and stored at -40°F until WBS evaluation. Vacuum seals were broken, and chops were thawed for 24 h at 37°F. Chops were weighed in the bag prior to thawing and weighed again out of the bag after thawing.

Chops taken at 11-in. were weighed, covered with a polyvinyl chloride wrap in 2S Styrofoam trays, and weighed for moisture loss calculations. Each chop was placed into an open-top retail display case for 24 h at 32°F. Chops then were removed from the case and weighed for further calculations of moisture loss.

All chops were cooked to an internal temperature of 160°F in a Blodgett dual-air-flow oven (DFG-201, G.S., Blodgett Co., Inc., Burlington, VT). Temperature was monitored using a thermocouple attached to a Doric Minitrend 205 temperature recorder (Emmerson Electric S.A., Doric Div., San

Diego, CA.). Chops then were cooled for 1 h and weighed again. They were chilled for 24 h at 38°F before six 0.5-in. cores were taken parallel to the muscle fibers and sheared perpendicular to the muscle fibers using a WBS apparatus attached to a Universal Instron testing machine (Model 4201, Instron, Canton, MA).

Percentages of thawing and cooking losses were calculated by the equations [(frozen wt.-thawed wt.)/frozen wt.] and [(raw wt. -cooked wt.)/raw wt.], respectively. Total percentage moisture loss was calculated by the equation [1-((1-purge, %) × (1- thawing loss, %) × (1-cooking loss, %))].

Results and Discussion

Effects of pH on WBS values and percentage moisture loss are reported in Table 1. No differences (P>.05) were observed for WBS. However, percentage cooking losses decreased with increased loin pH. Cooking losses at pH >6.2 were over 7% less than those at pH <5.5. The decrease in cooking loss tended to become less as pH increased. Chops with a pH of <5.5 had higher (P<.05) cooking losses than chops with pHs of 5.8 to >6.2. However, chops with a pH of 5.8 had higher (P<.05) cooking losses than chops with a pH of >6.2. Percentage total moisture losses were similar to cooking losses and decreased with increased loin pH. Losses for chops with a pH of <5.5 were over 6% higher than those for chops with a pH of >6.2. Chops with a pH of <5.5 had higher (P<.05) total moisture losses than chops with pHs of 5.9 to >6.2. However, chops with a pH of 5.9 had similar (P>.05) losses to chops with a pH of >6.2.

The quality characteristics for fresh and frozen chops are presented in Table 2. Chops that were frozen had lower (P<.05; more tender) WBS values than chops that were fresh. No differences (P>.05) were found for percentage cooking losses between fresh and frozen chops. However, fresh chops had lower (P <.05) total percentage moisture losses than frozen chops.

This study suggests that pH and freezing affect storage and cooking yield as well as WBS values. Frozen chops will have lower WBS values (more tender) and a higher total percentage of moisture loss than fresh chops.

Table 1. Influence of pH on Fresh and Frozen Chops

	Loin pH									
Variable	<5.5	5.5	5.6	5.7	5.8	5.9	6.0	6.1	>6.2	SE
WBS, kg	2.75	2.93	2.41	2.09	2.53	2.43	2.84	2.42	2.58	0.2802
Cooking loss, %	25.82^{e}	24.65^{de}	23.61^{cde}	21.93^{abcd}	22.26^{bcd}	21.05^{abc}	18.80^{ab}	18.84^{ab}	18.70^{a}	1.29
Total loss, %	31.21^{e}	30.75^{de}	29.36^{cde}	27.20^{abcd}	27.76^{bcde}	24.43^{ab}	26.33^{abc}	23.87^{a}	24.53^{ab}	1.24

^{a,b,c,d,e}Means within a row with different superscript letter differ (P<.05).

Table 2. Warner-Bratzler Shear Force and Cookery Traits of Fresh and Frozen Chops

Variable	Frozen	Fresh	SE
WBS, kg	2.23^{a}	2.88^{b}	0.118
Cooking loss, %	21.57	21.9	1.29
Total loss, %	29.4^{b}	25.14^{a}	0.051

^{a,b}Means within a row with a different superscript letter differ (P<.05).

ACKNOWLEDGEMENTS

Appreciation is expressed to these organizations for assisting with swine research at Kansas State University:

Alliance Farms, Yuma, CO
Amandus Kahl, Co., Reinbek, Germany
American Proteins Corporation, Ames, IA
Asgrow Seed Company, Halstead, KS
BioKyowa, Inc., St. Louis, MO
California Spray-Dry, Stockton, CA
Chelated Mineral Corp., Olatha, KS
Church and Dwight Co, Inc., Princeton, NJ
Darling International Research, Irving, TX
Dupont Quality Grains, Des Moines, IA
Eichman Farms, St. George, KS
Elanco Products Company, Indianapolis, IN
Farmland Industries, Kansas City, MO
Finn Feeds Int., Schaumburg, IL
Global Ventures, Pipestone, MN
Gro Master, Omaha, NE
Heartland, Lysine, Chicago, IL
Henry's LTD, Longford, KS
Hoffman-LaRoche, Inc., Nutley, NJ
IMC Agrico Feed Ingredients, Bannockburn, IL
Kansas Pork Producers Council, Manhattan, KS
Kansas Sorghum Commission, Topeka, KS
Kansas Soybean Commission, Topeka, KS
Kansas State Board of Agriculture, Topeka,
Kansas Swine Alliance, Abilene, KS
KCARE, Kansas State University
KS Keesecker Ag-business, Washington, KS
Kemin Industries, Des Moines, IA
Key Milling, Clay Center, KS
Livestock and Meat Industry Foundation, Manhattan, KS
Lonza, Inc., Fair Lawn, NJ
National Pork Producers Council, Des Moines, IA
NC+ Hybrids, Colwich, KS
Pipestone System, Pipestone, MN
Pork Packers International, Downs, KS
SAF Products, Minneapolis, MN
Seaboard Farms, Inc., Gymon, OK
Steven Cox Associates, Long Island, KS
Triple "F" Products, Des Moines, IA
Wenger Manufacturing, Inc., Sabetha, KS
Wilke International, Lenexa, KS
Zenith Project, Geneseo, KS
Zephyr Project, Geneseo, KS

We especially appreciate the assistance and dedication of Jason Woodworth, Mark Nelson, Lyle Figgy, Robert Beckley, Eldo Heller, and Theresa Rathbun.

We gratefully acknowledge Eileen Schofield for editorial assistance, Valerie Stillwell for word processing, and Fred Anderson for cover design for this publication.

Swine Industry Day Committee

Jim Nelssen, Chairman — Mike Tokach
Duane Davis — Joe Hancock
Steve Dritz — Bob Goodband

Contribution No. 01-138-S from the Kansas Agricultural Experiment Station.

Kansas State University Agricultural Experiment Station and Cooperative Extension Service, Manhattan 66506

SRP 858 October 2000