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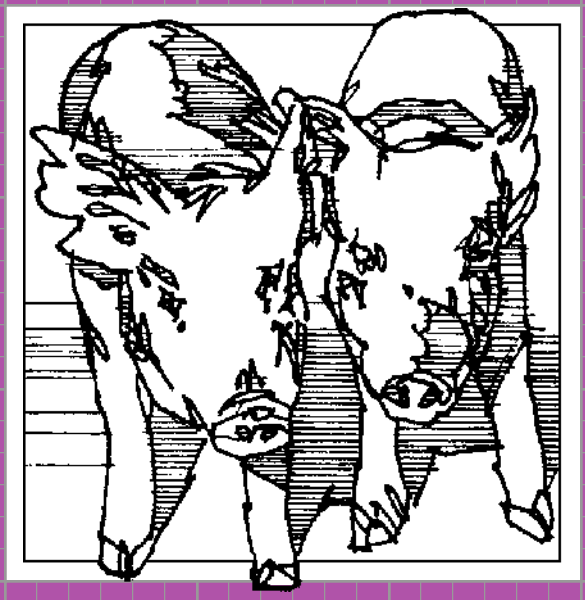

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SWINE DAY 2001

REPORT OF PROGRESS 880, KANSAS STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

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FOREWORD

It is with great pleasure that we present to you the 2001 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, 2001 Swine Day Report of Progress,

Bob Goodband Mike Tokach Steve Dritz

ABBREVIATIONS USED IN THIS REPORT

ADG	=	average daily gain	g	=	gram(s)	ml	=	cc (cubic centimeters)
ADFI	=	average daily feed intake	gal	=	gallon(s)			
			GE	=	gross energy	mo	=	month(s)
avg	=	average	h	=	hour(s)	µg	=	microgram(s)
BW	=	body weight	in	=	inch(es)		=	.001 mg
cm	=	centimeter(s)	IU	=	international unit(s)	N	=	nitrogen
CP	=	crude protein				ng	=	nanogram(s)
CV	=	coefficient of variation	kg	=	kilogram(s)		=	.001 µg
			Kcal	=	kilocalorie(s)	no.	=	number
cwt	=	100 lb	lb	=	pound(s)	ppm	=	parts per million
d	=	day(s)	Mcal	=	megacalorie(s)	sec	=	second(s)
DM	=	dry matter	ME	=	metabolizable energy	SEW	=	segregated early weaning
°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.

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BIOLOGICAL VARIABILITY AND CHANCES OF ERROR

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

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

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

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

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

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Swine Day 2001

INTERACTIVE EFFECTS OF ADDED L-CARNITINE AND CHROMIUM PICOLINATE ON SOW REPRODUCTIVE PERFORMANCE [1]

D. E. Real, J. L. Nelssen, M. D. Tokach, R. D. Goodband, S. S. Dritz [2], K. Q. Owen [3], and S. Stoller

Summary

A total of 599 sows were used to determine the effects of added L-carnitine and/or chromium picolinate on reproductive performance. Experimental treatments were arranged in a 2 × 2 factorial with main effects of added L-carnitine (0 or 50 ppm) and chromium picolinate (0 or 200 ppb). Starting on the first day of breeding, sows were provided a daily top dress containing the carnitine and(or) chromium along with the standard gestation diet. Dietary treatments were administered daily through the initial gestation, lactation, and through a second gestation period (2 parities). During the first parity, there was a carnitine × chromium interaction (P<0.01) for first service farrowing rate. Added dietary chromium increased (P<0.01) first service farrowing rate, but not when carnitine was added. No differences (P>0.05) were observed in number of pigs born alive, still born, mummies, or total born in the first parity. Added dietary L-carnitine decreased (P<0.05) wean to estrus interval, and tended to increase (P<0.08) the number of sows in estrus by d 7. In the second parity, a tendency (P<.08) for a carnitine × chromium interaction was found for first service farrowing rate. Adding carnitine and chromium together in the diet increased first service farrowing rate compared to either product alone. Because of the change in wean-to-estrus interval and farrowing rate, feeding additional dietary carnitine and chromium increased (P<0.04) the percentage of sows that were weaned from parity 1 and farrowed in parity 2. When calculating the total number of pigs and number born alive based on all sows that were started on test, both added carnitine and chromium increased the number of pigs born and born alive. These results show that carnitine and chromium supplementation improved return-to-estrus interval and farrowing rate and, thus, total number born alive over two parities.

Introduction

Carnitine is a water soluble, vitamin-like compound that functions to transport fatty acids across the mitochondria membrane where they are processed to produce energy. However, carnitine may play a greater role in metabolism than just fatty acid transport. Recent studies have observed increases in the total number of pigs born and born alive by feeding L-carnitine during gestation or lactation.

Chromium is a trace mineral that is actively involved in the metabolism of carbohydrates, lipids, proteins, and nucleic acids in the body. Chromium potentiates insulin action by increasing the cellular uptake of glucose and intracellular carbohydrate and lipid metabolism. Studies have shown that feeding chromium in gestation and lactation increases number of pigs born alive, and some studies have observed increased farrowing rate. Because both of

[1]Authors would like to thank Rod and Ellen Evert of Zenith Farms, Little River, KS for help in data collection and trial facilitation.

[2]Food Animal Health and Management Center.

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

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these nutrients influence sow reproductive performance, the objective of our study was to compare carnitine and chromium on sow reproductive performance. In addition, a second objective was to determine if the responses to carnitine and chromium were additive.

Procedures

This experiment was conducted on a commercial 1,500 sow farrow-to-wean operation in central Kansas and used 599 sows (PIC Line C22). Sows were started on test on the first day of breeding. Each sow remained on the same treatment through gestation, lactation, and through a second gestation period (2 parities). During gestation, all sows were fed a milo-soybean meal-based diet formulated to contain 0.65% lysine, 0.83 % Ca, and 0.76% P. In lactation, all sows were fed a grain sorghum-soybean meal-based diet formulated to contain 1.10% lysine, 0.90% Ca, and 0.80% P (Table 1). Dietary treatments were provided via a corn-based top dress fed at 30 g/d. The top dress was formulated to provide 90 mg/d and 250 mg/d carnitine in gestation and lactation, respectively. Chromium was provided at 360 mcg/d and 1,000 mcg/d during gestation and lactation, respectively. These inclusions were calculated to provide 50 mg/kg carnitine and 200 mcg/kg chromium when sows were fed 4 lb/d of the gestation diet and 11 lb/d of the lactation diet. The top dress was also color coded (1% died corncobs) by treatment to assure proper distribution of experimental treatments.

At farrowing, the number of pigs born alive (NBA), as stillborn (SB), as mummies (MUM), and total born (TB) were recorded. Sows were rebred after weaning (15 d lactation) and remained on the same treatment until farrowing a second litter. If a sow did not return to estrus within 18 days, she was taken off test. Sows that were bred at the start of the study, but were later found open, were taken off test when estrus was detected. Procedures and data collection were identical for the second gestation and lactation period. However, dietary treatments were not administered during the second lactation period.

Calculations were made to determine the total number per sow of pigs born, born alive, as stillborns, or as mummies for the two parities. Total number of pigs were calculated using only sows that initially farrowed, then completed the second parity, as well as calculated from all the sows that were actually started on test.

Data were analyzed using the MIXED procedure of SAS. Sow was the experimental unit for the analysis with parity, previous lactation length, and/or week of farrowing was a covariate (Table 2) for TB, NBA, MUM, and SB. A chi-square statistic was calculated to determine differences among treatments when analyzing percentage in estrus and farrowing rate.

Results and Discussion

In the first parity, a carnitine × chromium interaction ($P<0.01$) was observed for first service farrowing rate (Table 2). Added dietary chromium improved ($P<0.01$) first service farrowing rate, but there was no added benefit with adding carnitine. There were no differences ($P>0.10$) in the total number of pigs born, born alive, or born mummified. However, sows fed added chromium tended to have increased ($P<0.07$) number of stillborn pigs/litter. Adding dietary carnitine improved ($P<0.05$) wean to estrus interval and tended to increase ($P<0.08$) the number of sows in estrus by d 7.

In parity 2, a tendency ($P<.08$) for a carnitine × chromium interaction was found for first service farrowing rate of sows. Adding carnitine and chromium together in the diet increased first service farrowing rate, while adding either carnitine or chromium alone did not influence farrowing rate. Feeding additional dietary carnitine and chromium increased ($P<0.04$) the percentage of sows that were weaned from parity 1 and farrowed in parity 2. This calculation is a combination of the return to estrus interval and farrowing rate. In parity 2, there were no differences ($P<0.19$) among treatments for total number of pigs born, born alive, stillborn, or born mummified. There were also

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no differences (P>0.14) among treatments for wean to estrus interval or percentage of sows returning to estrus by d 7 or 18.

We then calculated the total number of pigs born, born alive, still born, and born mummified over the entire trial for those sows that completed parity one (123, 140, 138, and 142, for control, added carnitine, added chromium, and both, respectively). This calculation resulted in sows fed added carnitine having more (P<0.05) total pigs, and pigs born alive. A second calculation using all the sows that were started on test, showed that total pigs and pigs born alive were increased (P<0.02) for sows fed added carnitine, and(or) chromium. No carnitine × chromium interactions (P>0.10) were observed for these response criteria, suggesting that the response to carnitine and chromium are additive. It also suggests that the two nutrients may improve sow reproductive functioning by different mechanisms.

In conclusion, supplementing gestation and lactation diets with added carnitine and chromium had minimal effects on the number of pigs born alive per litter; however, the improvements in return-to-estrus interval and farrowing rate resulted in greater overall number of pigs born for the two parity studies. These data are novel in that they are the first to examine the effects of combining added carnitine and chromium on sow reproductive performance. These data suggest that improvements in reproductive performance from the two nutrients is additive and that carnitine and chromium appear to be working via different mechanisms to improve sow productivity.

Table 1. Common Diet Compositions[a]

Ingredient, %	Gestation[b]	Lactation[c]
Diet		
Grain sorghum	80.18	64.10
Soybean meal (46.5%)	15.68	31.75
Other vitamin and trace mineral additions[d]	4.04	4.15
Total	100.00	100.00
Top dress[e]		
Corn[f]	99.00	99.00
Corncobs[g]	1.00	1.00

[a]All sows fed similar basal diet.
[b]Sows were fed 4 lb/d during gestation; (0.7% lysine, 0.83% Ca, and 0.76% P).
[c]Sows were fed ad libitum during lactation; (1.0% lysine, 0.90% Ca, and 0.80% P).
[d]Provided 10,000,000 IU vitamin A, 1,500,000 IU vitamin D_3, 40,000 IU vitamin E, 4,000 mg menadione, 40 mg vitamin B_{12}, 9,000 mg riboflavin, 30,000 mg pantothenic acid, 50,000 mg niacin, 150 g zinc, 150 g iron, 36 g manganese, 15 g copper, 270 mg iodine, 270 mg selenium, 500,000 mg choline, 200 mg biotin, 1,500 mg folic acid, and 13,750 mg pyridoxine per ton of diet.
[e]Fed to sows at 30 g/d to disperse dietary treatments.
[f]L-carnitine and/or chromium replaced corn to achieve dietary supplementation of 90 mg/d carnitine in gestation, 250 mg/d carnitine in lactation, 360 mcg/d chromium in gestation, and 1000mcg/d chromium in lactation.
[g]Colored corncobs were added to distinguish treatments from one another.

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Table 2. Effects of L-Carnitine and Chromium Picolinate on Reproductive Performance[a]

	Treatment					Probabilities, P<		
Item	Control	Carnitine[b]	Chromium[c]	Both[bc]	SEM	Carnitine	Chromium	Int.
First parity								
No. of sows								
Started on test	148	150	147	154				
Farrowed	123	140	138	142				
First service FR, %[dei]	82.9	91.9	95.5	92.2	2.38	0.22	0.01	0.01
No. of pigs								
Total born[e]	11.3	11.4	11.5	11.6	0.30	0.62	0.57	0.90
Born alive[e]	10.0	9.8	10.2	10.2	0.25	0.32	0.63	0.71
Still born[e]	0.95	0.98	1.26	1.13	0.130	0.68	0.07	0.52
Mummies	0.34	0.26	0.39	0.34	0.060	0.26	0.29	0.77
WEI, d[dgh]	4.9	4.6	4.7	4.5	0.01	0.05	0.23	0.75
% estrus by d 7[egi]	84.8	88.6	86.7	92.3	2.88	0.08	0.31	0.73
% estrus by d 18[egi]	88.1	91.5	91.7	94.4	2.49	0.20	0.17	0.89
Second parity								
No. of sows								
Weaned parity 1	123	140	138	142				
Bred by d 18	108	128	127	134				
Farrowed	87	104	102	122				
First service FR, %[degi]	81.2	81.3	79.7	91.1	3.49	0.07	0.20	0.08
Percent of weaned	70.7	73.9	74.3	85.9	3.81	0.04	0.03	0.24
No. of pigs								
Total born[eg]	11.1	11.2	11.0	11.4	0.37	0.50	0.94	0.81
Born alive[eg]	9.7	9.9	9.5	9.8	0.33	0.53	0.62	0.89
Still born[e]	1.02	1.02	1.09	1.31	0.149	0.43	0.19	0.45
Mummies	0.35	0.33	0.40	0.25	0.071	0.22	0.88	0.29
WEI, d[dgh]	4.6	4.7	4.6	4.8	0.01	0.14	0.94	0.46
% estrus by d 7[efgi]	80.3	76.9	81.0	75.0	4.32	0.23	0.88	0.75
% estrus by d 18[efgi]	80.2	80.8	82.9	75.9	4.17	0.40	0.77	0.32
Total pigs per sow for sows that completed parity one								
Total born[eg]	19.4	19.8	19.5	21.3	0.59	0.04	0.15	0.25
Born alive[eg]	17.1	17.6	16.8	18.5	0.53	0.03	0.55	0.24
Still born[e]	1.7	1.7	2.1	2.3	0.19	0.46	0.01	0.66
Mummies	0.6	0.5	0.6	0.6	0.08	0.17	0.43	0.85
Total pigs per sow of all sows started on test for two parities								
Total born[eg]	15.8	18.4	18.8	19.7	0.71	0.01	0.003	0.24
Born alive[eg]	13.9	16.3	16.2	17.0	0.63	0.01	0.02	0.23
Still born[e]	1.4	1.6	2.0	2.1	0.17	0.35	0.002	0.94
Mummies	0.5	0.5	0.7	0.5	0.71	0.27	0.16	0.42

[a]Initially 599 sows bred. [b]50 mg/kg L-carnitine provided as top dress daily. [c]200 mcg/kg chromium picolinate provided as top dress daily. [d]FR = First service farrowing rate; WEI = wean to estrus interval. [e]Parity was used as a covariate; 6.0, 5.6, 5.2, and 5.5 for control, carnitine, chromium, and both, respectively. [f]Previous lactation length was used as a covariate; 15.2, 15.8, 15.7, and 15.4 for each treatment. [g]Week of year sow farrowed was used as a covariate; 23.6, 23.9, 23.7, and 23.9 for each treatment. [h]WEI analyzed as inverse of means, previous WEI analyzed as log of means. [i]P-values from chi-square statistic.

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THE RELATIONSHIP BETWEEN BODY CONDITION SCORE AND BACKFAT IN GESTATING SOWS [1]

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

Summary

Backfat and body condition score were measured on 731 sows in a commercial swine facility to assess the accuracy of feeding sows in gestation based on body condition score. Body condition score was poorly correlated ($r^2 = 0.19$) with backfat thickness. For example, sows assessed with a body condition of 3 ranged in backfat from 0.3 to 0.9 in. (7.5 to 23 mm). This illustrates the need to find a more objective method of measuring body condition (such as ultrasound) in order to properly adjust feeding levels and thus reduce variation in backfat of sows.

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

Introduction

In many commercial swine production systems in North America, gilts and sows are fed based on a body condition score (BCS). Typically a scale of 1 to 5 is used, with 1 being very thin, 3 intermediate and 5 very fat. This is a very subjective system and varies from one assessor to the next. Body condition score (BCS) and backfat thickness appear to be poorly correlated. In a Canadian study, sows with a BCS of 3, ranged in backfat from 0.37 to 1.1 in. (9 to 28 mm). Additional data on backfat measurement and assessment of body condition of sows on three farms in Minnesota showed that between 18 to 40% of sows had backfat levels less than 0.51 in. (13 mm). Also, sows assessed on a body condition score of 3 had a range in backfat thickness from 0.37 to 0.98 in. (9 to 24 mm). Generally it is recommended that less than 20% of sows should be below 0.59 in. (15 mm) of backfat.

Our long-term goal is to develop a method to feed gestating sows based on backfat and body weight category. Our goal is to reduce the variability in backfat of sows in gestation and to farrow sows at approximately 0.75 in. (19 mm) of backfat at the last rib. The first step in this process is to determine the variability in backfat in commercial herds. Thus, our objective in this study was to determine the variability of sow backfat thickness in a commercial sow farm throughout gestation for sows fed based on a body condition scoring system.

Procedures

The study was conducted on a commercial swine operation in central Kansas. Sows were housed individually in stalls in environmentally regulated facilities. Gestation stalls were 24 in. × 7 ft over a completely slatted floor. Backfat was measured on all sows (1,306) at approximately 2.6 in. from the midline at the last rib using a lean-meater (Renco Corporation, Minneapolis, MN). Backfat was measured on both sides of the midline and averaged to determine backfat thickness. Girth was also measured directly behind the front legs on all sows and used to categorize sows into weight classes. A corre-

[1]Appreciation is expressed to Dr. Lisa Tokach, Abilene Animal Hospital, Abilene, KS, and Rod Evert, Sow Farm Manager, for their assistance with the study.

[2]Food Animal Health and Management Center.

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lation for girth (body circumference) to body weight ($r^2 = 0.85$) was obtained, by weighing 90 sows and measuring their girth at the KSU swine teaching research center, and was used to categorize sows into classes.

Girth (in.)	Weight (lb)	Class
43 to 47	250 to 325	Very light
47.1 to 51	325 to 400	Light
51.1 to 54	400 to 475	Medium
54.1 to 60	475 to 600	Heavy

A total of 1,106 sows were in the gestating barn and 200 sows were in farrowing rooms. Sows were fed a milo-soybean meal diet containing 0.65% lysine, 1455 kcal/lb, 0.83% calcium and 0.49% available phosphorous in gestation. In lactation sows were fed a milo-soybean meal diet containing 1.10% lysine, 1458 kcal/lb, 0.9% calcium and 0.49% available phosphorous. In the gestation barn, sows had individual feed drop boxes and were fed once daily at 7:30 am. In the farrowing rooms, sows were fed 3 to 5 times daily to achieve maximum feed intake. Parity of all sows was recorded at the time of backfat measurements.

The farm manager scored the sows for body condition during the same week that backfat was measured. A scale of one to five was used, with one being very thin, three being intermediate, and five being very fat. Feeder box settings for all sows were documented and used to compare with sow backfat thickness and body condition scores. Correlation coefficients were calculated to determine the relationship between body condition score and backfat.

Results and Discussion

From Table 1 and Figure 1, there is a positive relationship between backfat thickness and body condition score, but the relationship was poor with an $r^2 = 0.19$. The sows with a body score of three had an average backfat thickness of 0.54 in. (13.7 mm) with a minimum of 0.30 in. (7.5 mm) and a maximum of 0.91 in. (23 mm). The sows with a body condition score of one had an average backfat thickness of 0.40 in. (10.1 mm), with a minimum of 0.28 in. (7 mm) and a maximum of 0.53 in. (13.5 mm). As backfat thickness increased the body condition score increased, but there was a wide range in backfat at each body condition score.

The average backfat thickness for the entire herd was 0.53 in. (13.6 mm), which is very similar to the average of sows with a body condition score of three. Sow backfat thickness was normally distributed, with 25% of sows less than 0.47 in. (12 mm), and 68% of sows less than the recommended goal of 0.59 in. (15 mm). In the first five weeks of gestation, sow backfat thickness was in a narrow range between 0.51 in. and 0.55 in. (13 to14 mm; Figure 3). There was a trend towards a slight increase in backfat in midgestation. However, this data must be interpreted with caution because the data was collected as a snapshot of the herd at one point in time and not through serial measurements on the same sows. In the last trimester of gestation, there is little change in backfat, with a small decline, if anything, to farrowing. In the last four weeks of gestation, the higher demand for fetal growth does not seem to be fully met from daily feed allowance, as sows seem to be drawing from there own body reserves to fully meet fetal growth requirements.

Although there was a relationship between backfat thickness and feeding level (Figure 4), the relationship was highly variable ($r^2 = 0.15$). For example, backfat ranged from 0.30 to 0.87 in. (7.5 to 22 mm) for sows that were being fed 4 lb per day. Approximately two weeks prior to backfat measurements, feeders had been adjusted upwards by the farm manager because he felt sow body condition was too low. Even with these adjustments, a large range in backfat at each feed level was still evident in Figure 4.

A regression equation (Weight (lb) = 20.94 × Girth (in.) ! 650; $r^2 = 0.85$) was developed to predict sow weight from girth. Girth was measured directly behind the front legs of sows. As sow parity increased, girth and predicted body weight increased steadily up to parity five, after which girth and weight continues to increase but at a more gradual rate to parity ten. The largest in-

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crease in girth and predicted body weight was when sow parity increased from one to three, as this is the period where sows reach their mature physical size.

From this data, it is clear that body condition score is not an accurate method on which to base a sow feeding program. Body condition scoring of sows is subjective, and even with excellent farm managers, there is still too much variation in backfat at each condition score. These results emphasize the need to find a more accurate method of feeding sows in gestation to reduce the variation in sow backfat. We are in the process of testing a system of feeding sows in gestation based on ultrasonic measurement of backfat recorded shortly after breeding. We are currently validating this method on sow farms.

Table 1. Body Condition Score and Backfat Thickness for Sows[a]

	Backfat[b]					
	Average		Minimum		Maximum	
Body Condition Score	Inch	mm	Inch	mm	Inch	mm
1	0.40	10.1	0.28	7.0	0.53	13.5
2	0.47	11.9	0.28	7.0	0.87	22.0
3	0.54	13.7	0.30	7.5	0.91	23.0
4	0.62	15.8	0.47	12.0	0.93	23.5
5	0.70	17.8	0.35	9.0	0.83	21.0

[a]A total of 731 sows were measured.
[b]Backfat was measured at the approximately 2.6 in. from the midline on both sides of the mid-line and averaged.

Table 2. Average Sow Girth by Parity and Predicted Sow Weight

		Girth (in.)			Predicted Avg.
Parity	Number[a]	Average	Minimum	Maximum	Weight (lb)[b]
1	258	49.5	42.5	58.5	387
2	248	53.5	48.0	59.5	470
3	169	55.8	50.0	62.5	518
4	185	56.4	51.0	63.0	531
5	141	57.4	51.5	64.0	552
6	93	57.7	52.0	62.5	558
7	84	58.6	54.0	63.5	577
8	27	58.5	54.5	62.0	575
9	34	58.9	56.5	62.5	583
10	15	59.1	57.0	63.0	588
11	28	58.5	55.0	63.0	575
12	24	56.1	54.5	63.0	525

[a]Total number of sows 1,306.
[b]Predicted Avg. Weight (lb) = 20.94 (Avg. Girth, in.) ! 650.

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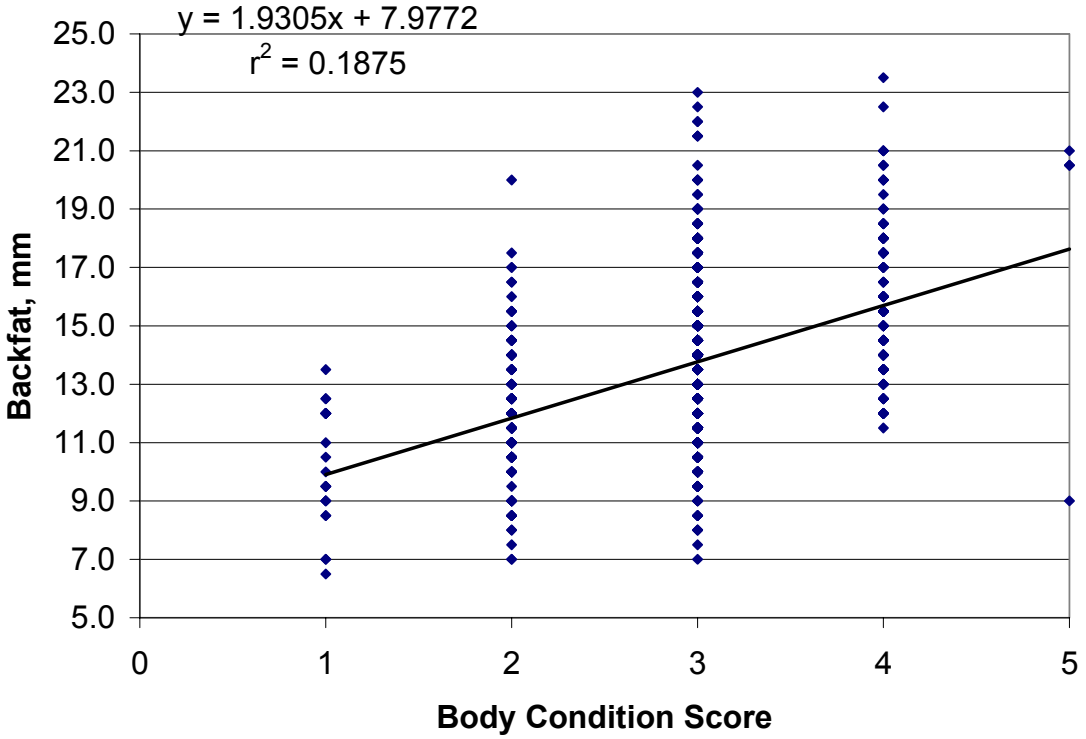

Figure 1. The Relationship Between Body Condition and Backfat Thickness for Gestating Sows. A total of 731 sows were ultrasonically scanned at the last rib and correlated with a body condition score (1 = thin; 5 = fat) that was assigned by the farm manager.

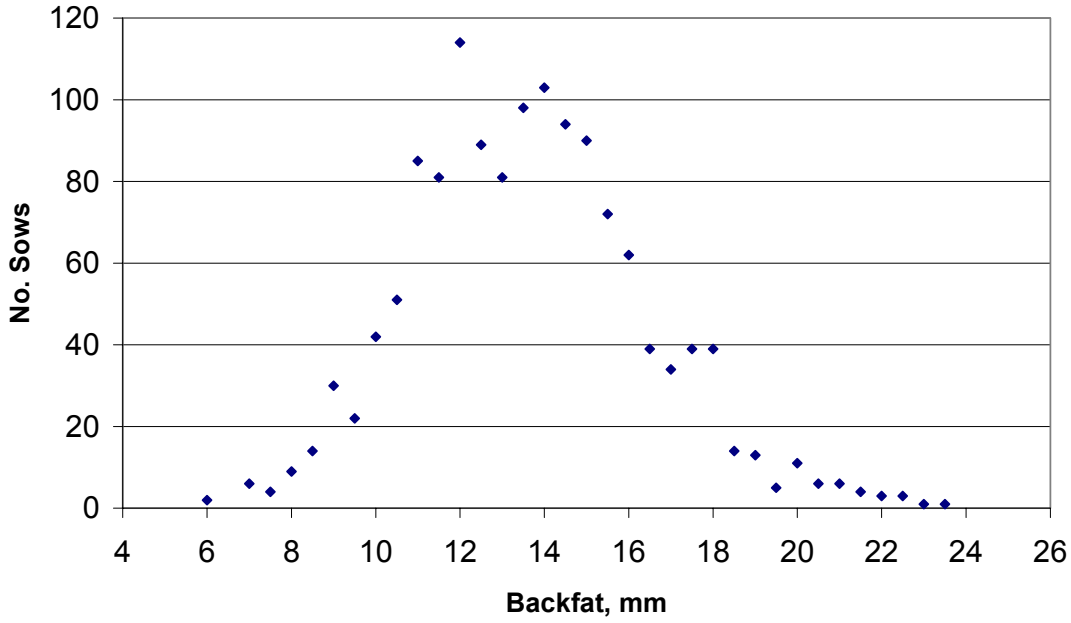

Figure 2. Frequency Distribution of the Number of Sows at Each Backfat Thickness. A total of 1,306 sows were ultrasonically scanned for backfat thickness at the last rib.

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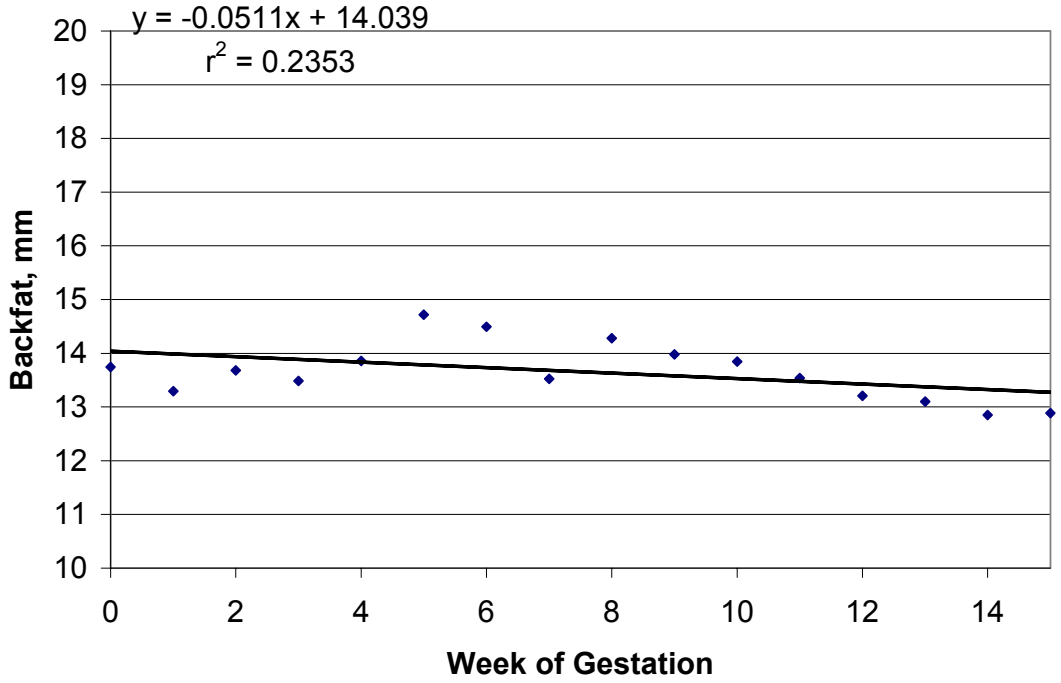

Figure 3. Backfat Thickness at Each Week of Gestation in Sows. Values represent approximately 65 sows for each week of gestation. All sows were scanned on the same day.

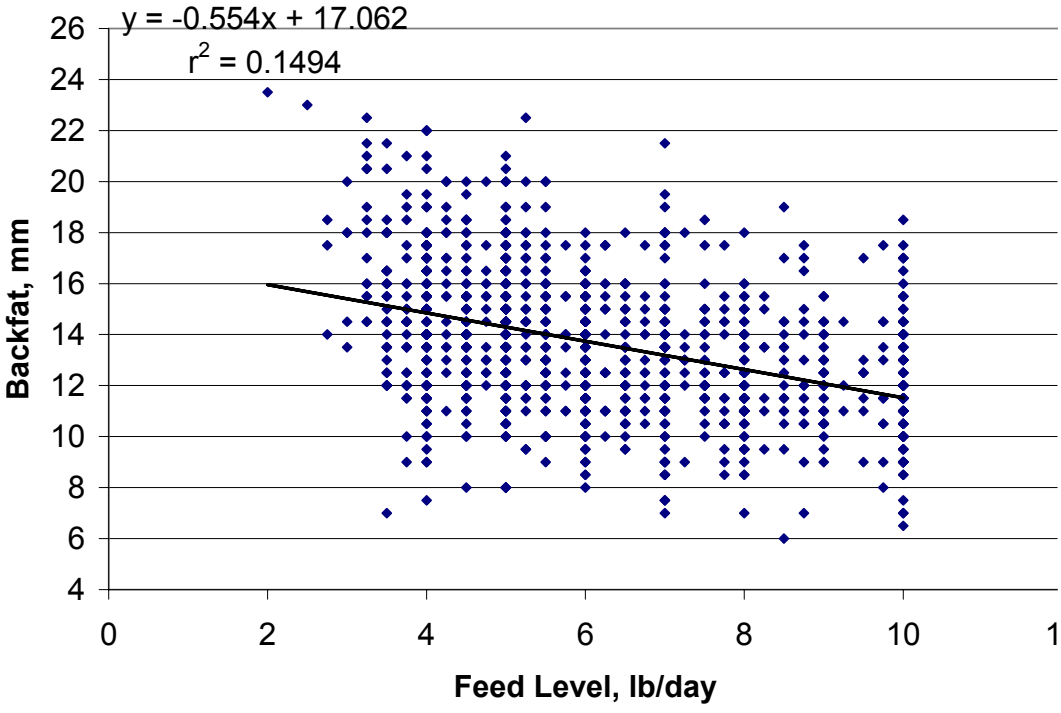

Figure 4. The Relationship Between Feeding Level and Backfat Thickness for Gestating Sows. A total of 1,306 sows were scanned and correlated with their feed intake.

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COMPARISON OF IRRADIATED FEED AND FOOD GRADE SPRAY-DRIED ANIMAL PLASMA ON NURSERY PIG PERFORMANCE

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

Summary

Two experiments were conducted to determine the effects of initial bacterial concentrations in animal plasma on growth performance of weanling pigs. In Exp. 1 during the experimental period (d 0 to 14), pigs fed plasma had increased ADG and ADFI compared to pigs fed the control diet. Pigs fed the irradiated AP 920, as well as source 1 and source 2 regular (nonirradiated) food grade plasma had increased ADG compared to the control diet. Furthermore, pigs fed irradiated AP 920, regular AP 820, regular and irradiated source 1 food grade and regular source 2 food grade animal plasma had improved ADFI compared to pigs fed the control diet. No differences in F/G were observed between treatments. No differences were detected between pigs fed diets that contained irradiated plasma compared to those fed it in the regular form. For the overall experiment (d 0 to 24), pigs fed irradiated AP 920 had a tendency for improved F/G compared to pigs fed the control diet. In Exp. 2 during the experimental period (d 0 to 14), pigs fed diets containing plasma had improved ADG and F/G compared to pigs fed the control diet. Pigs fed irradiated AP 820 food grade plasma had higher ADG compared to pigs fed regular AP 820. For the overall experiment (d 0 to 24), pigs fed diets containing irradiated AP 820 had increased ADG, final body weight, and ADFI compared to pigs fed regular AP 820. Since irradiation of food grade plasma (low initial bacteria) did not improve growth performance while irradiation of feed grade plasma (initially high bacteria) improved performance, the initial bacteria level of animal plasma appears to influence growth performance of nursery pigs.

(Key Words: Nursery Pigs, Animal Plasma, Irradiation.)

Introduction

We have recently shown that nursery pig performance can be improved when irradiated feed grade animal plasma is fed compared to animal plasma that has not been irradiated. The mode of action of this increase in performance is unclear, but one theory is the response is due to a reduction in the bacterial concentration resulting from irradiation. Animal blood used for food grade plasma is collected in a more controlled procedure than blood collected for feed grade plasma. Thus, food grade plasma has a lower initial total bacterial concentration. In addition, bacterial concentrations increase as storage time increases from the collection of the blood from the animal until the time the blood is spray-dried. Thus, the use of food grade plasma subjected to different storage times and irradiation may serve as a model to determine whether the improvement in pig performance is due to the reduction in bacterial concentration or another factor.

Materials and Methods

Experiment 1. A total of 360 weanling pigs (BW of 13.8 lb and 17 ± 2 d of age) were used in a 24-d growth assay. Pigs were blocked by weight and allotted to one of nine

[1]Food Animal Health and Management Center.

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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 waterer 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.

Experimental diets (Table 1) were fed in pelleted form and included a control diet or the control diet with 5% spray-dried animal plasma from one of four different sources from American Protein Corporation, Ames, IA (AP 920, AP 820, food grade low bacteria, food grade high bacteria). All animal plasma sources were either fed irradiated or as-is, and originated from the same lot for each source. In addition, diets containing AP 820 and food grade plasma had slightly lower amino acid contents compared diets with AP 920, because they had a lower CP (72 vs. 79%) level. Irradiated animal plasma was processed with an average dose of 8.5 kGy via electrical pasteurization. All pigs were switched to a common diet that was in meal form on d 14 for the remainder of the trial. Plasma samples were collected prior to feed manufacturing and analyzed for levels of crude protein, IgG, endotoxin, bacteria, coliforms, and *E. coli*. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 7, 14, and 24 postweaning.

Experiment 2. A total of 175 pigs (13.4 lb and 17 ± d) were used in a 24-d growth assay. The experimental design, housing and care of pigs, and response criteria were similar to that used in Exp. 1, except there were seven pens/treatment. Also, this study included only five of the nine experimental diets from Exp. 1, which included the control diet, and the control diet containing AP 820 (irradiated and as-is) or food grade animal plasma (irradiated and as-is). The animal plasma sources used in this study originated from different lots than that of Exp. 1. Irradiated animal plasma was processed with an average dose of 8.0 kGy via electrical pasteurization.

The MIXED procedures of SAS were used for all statistical analyses, with pen as the experimental unit. Contrasts were used to determine the following: 1) Control versus all plasma added treatments; 2) Control versus regular plasma (nonirradiated); and 3) Irradiated versus regular plasma (non-irradiated).

Results

Experiment 1. Analysis of the animal plasma sources demonstrated that electrical pasteurization decreased bacterial concentrations for all sources used in this study (Table 2). In addition, AP 920 and AP 820 had substantially higher bacterial levels than the two food grade sources, which was anticipated. Bacterial concentrations of the two food grade sources were very low regardless of source with little to no differences between the two sources. In fact, the plasma source initially believed to be the higher bacterial concentration was actually slightly lower in bacterial level than the selected low bacteria plasma lot. Since no major differences existed in the bacterial concentrations of the food grade plasma, they will be referred to as source 1 and source 2. Also, total coliforms and *E. coli* concentrations were below detectable levels except for the low bacteria food grade plasma in Exp. 1. Furthermore, irradiation did not influence the crude protein, IgG, or endotoxin concentration of plasma, when comparing the regular and irradiated individual plasma sources.

For d 0 to 7, pigs fed any of the diets containing animal plasma, regardless of source, had improved ADG, ADFI, and F/G ($P<0.05$) compared to pigs fed the control diet (Table 3). Pigs fed both regular and irradiated AP 820 tended ($P<0.10$) to have improved F/G compared to those fed the control diet. No differences in growth performance were detected between pigs fed diets that contained irradiated plasma and those fed it in the regular form.

For d 7 to 14, no differences were detected among experimental treatments except that pigs fed source 2 food grade plasma tended to have improved F/G compared to pigs fed the control diet. During the overall

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treatment period (d 0 to 14), pigs fed plasma had increased ADG and ADFI (P<0.05) compared to pigs fed the control diet. Pigs fed irradiated AP 920, as well as source 1 and source 2 regular food grade plasma had increased ADG (P<0.05) compared to the control diet. Pigs fed irradiated AP 920, regular AP 820, regular and irradiated source 1 food grade and regular source 2 food grade had improved ADFI (P<0.05) compared to pigs fed the control diet. No differences in F/G were observed among treatments. No differences were detected between pigs fed diets that contained irradiated plasma and those fed it in the regular form.

From d 14 to 24 (common period), pigs fed irradiated AP 920 had a tendency for decreased ADFI (P<0.10) compared to pigs fed the control diet. For the overall experiment (d 0 to 24), pigs fed irradiated AP 920 had a tendency (P<0.10) for improved F/G compared to pigs fed the control diet. No other differences in growth performance were detected among treatment diets.

Experiment 2. Chemical analyses of the plasma used in this experiment closely matched results of Exp. 1 (Table 4).

For d 0 to 7, pigs fed diets containing animal plasma had improved ADG, ADFI, and F/G (P<0.05) compared to pigs fed the control diet (Table 5). Also, pigs fed irradiated AP 820 had a tendency for increased ADG and ADFI (P<0.10) compared to pigs fed regular AP 820.

From d 7 to 14, no significant effects were detected when comparing diets containing plasma versus the control diet. However, pigs fed irradiated AP 820 had greater ADG (P<0.05) and tended to have increased ADFI (P < .10) compared to pigs fed regular AP 820. Overall (d 0 to 14), pigs fed plasma had improved ADG and F/G (P<0.05) compared to pigs fed the control diet. Also, pigs fed either irradiated AP 820, regular food grade or irradiated food grade plasma had increased ADG (P<0.05) compared to the control diet. Pigs fed irradiated AP 820 food grade plasma had higher ADG (P<0.05) compared to pigs fed regular AP 820.

For d 14 to 24 (common period), ADFI was greater (P<0.05) for pigs previously fed irradiated AP 820 and tended (P<0.10) to be higher for pigs fed the control diet compared to pigs fed diets containing regular AP 820. Overall (d 0 to 24), no benefit in growth performance (P>0.10) was detected for pigs fed diets containing plasma when comparing the pooled average of treatments containing plasma versus the control diet. However, pigs fed diets containing irradiated AP 820 had increased ADG, final body weight, and ADFI (P<0.05) compared to pigs fed regular AP 820. In addition pigs fed irradiated AP 820 tended (P<0.10) to have increased ADG and final body weight compared to pigs fed the control diet.

Results from these experiments indicate that initial bacterial levels in animal plasma may affect the growth response in pigs fed irradiated plasma. This is supported by the fact that no improvements in growth performance were detected from the irradiation of food grade plasma, which has a low amount of initial bacteria. Although no irradiation effects were detected in Exp. 1, pigs fed irradiated AP 920 had increased ADG compared to the control pigs, whereas pigs fed regular AP 920 did not. The effects of irradiation of AP 820 on growth performance differed between the two experiments, a significant response for improved growth was observed in the second experiment. In all experiments to date, only irradiation of feed grade animal plasma, which has a high initial bacteria level, has resulted in improved growth performance when it is fed in the irradiated form compared to the regular form (nonirradiated).

Irradiation does not effect the analyzed chemical composition of animal plasma at the dosage used in this study. Other unknown anti-nutritional factors associated with feed grade plasma may be preventing maximum performance in nursery pigs that irradiation may reduce or eliminate. However, the results of this experiment support the hypothesis that a reduction in bacteria level is he reason that irradiation of animal plasma improves growth performance.

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Table 1. Composition of Experimental and Common Diet (Exp. 1 and 2)

	Treatment Diets[a]			
Ingredient, %	No Plasma[c]	AP 920[d]	Other Plasma Sources	Common[b]
Corn	36.47	43.91	43.91	46.97
Soybean meal (46.5%)	38.14	26.18	26.18	31.11
Spray-dried whey	15.00	15.00	15.00	10.00
Spray-dried animal plasma	-	5.00	5.00	-
Spray-dried blood cells	-	-	-	2.50
Soy oil	5.00	5.00	5.00	5.00
Medication[f]	1.00	1.00	1.00	1.00
Monocalcium phosphate (21% P)	1.55	1.44	1.44	1.29
Limestone	0.99	1.13	1.13	1.00
Salt	0.42	0.30	0.30	0.35
Sodium bicarbonate	0.38	-	-	-
Zinc oxide	0.39	0.39	0.39	0.25
Vitamin premix	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15
L-lysine HCl	0.15	0.15	0.15	0.05
DL-methionine	0.09	0.11	0.11	0.09
L-threonine	0.01	-	-	-
Total	100.00	100.00	100.00	100.00
Calculated Analysis				
Lysine, %	1.50	1.50	1.46	1.40
Met:lysine ratio, %	29	28	28	29
Met & cys:lysine ratio,%	55	58	58	55
Threonine:lysine ratio, %	62	64	64	62
Tryptophan:lysine ratio, %	20	19	19	20
ME, kcal/lb	1,560	1,580	1,574	1,573
Calcium, %	0.90	0.90	0.90	0.80
Phosphorus, %	0.80	0.80	0.72	0.70
Available phosphorus, %	0.51	0.46	0.45	0.41
Sodium, %	0.43	0.43	0.43	0.26
Chloride, %	0.53	0.53	0.60	0.43

[a]Diet fed from d 0 to 14 after weaning.
[b]Diet fed from d 14 to 28 after weaning.
[c]Exp. 1 and 2.
[d]Exp. 1 only.
[e]AP 820 and food grade plasma, Exp. 1 and 2.
[f]Provided 50 g per ton carbadox.

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Table 2. Chemical Analyses of Spray-Dried Animal Plasma (Exp. 1) [a]

	AP 920		AP 820		Food Grade Source 1		Food Grade Source 2	
Item	Regular	Irradiated	Regular	Irradiated	Regular	Irradiated	Regular	Irradiated
Crude protein, %	79.9	80.4	73.0	73.2	71.1	71.3	70.9	71.0
IgG, %	22.9	22.6	N/A[b]	18.6	16.3	16.5	16.3	15.3
Endotoxin, ng/g	7,116	21,388	N/A[b]	249,740	3,962	16.4	4.8	62.2
Aerobic plate count, cfu/g	$> 3.0 \times 10^5$	1.0×10^2	1.7×10^4	$< 1.0 \times 10^2$	6.5×10^3	$< 1.0 \times 10^2$	7.0×10^2	1.0×10^2
Total coliforms, cfu/g	< 3.0	< 3.0	< 3.0	< 3.0	2.3×10^1	< 3.0	< 3.0	< 3.0
E. coli, cfu/g	< 3.0	< 3.0	< 3.0	< 3.0	2.3×10^1	< 3.0	< 3.0	< 3.0

[a]Samples collected prior to complete diet manufacturing.
[b]Not available at time of publishing.

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Table 3. Effect of Irradiation on Various Types of Spray-Dried Animal Plasma on Growth Performance of Nursery Pigs (Exp. 1)[a]

		AP 920		AP 820		Food Grade Source 1		Food Grade Source		
Item	Control	Regular	Irradiated	Regular	Irradiated	Regular	Irradiated	Regular	Irradiated	SEM[g]
Initial wt, lb	13.87	13.85	13.85	13.89	13.85	13.86	13.83	13.88	13.89	0.75
d 0 to 7										
ADG, lb[b]	0.42	0.51[c]	0.57[e]	0.53[c]	0.53[e]	0.56[c]	0.58[e]	0.60[c]	0.58[e]	0.04
ADFI, lb[b]	0.37	0.45[c]	0.47[e]	0.45[c]	0.44[e]	0.48[c]	0.50[e]	0.51[c]	0.47[e]	0.03
F/G[b]	0.93	0.89	0.86	0.84[d]	0.84[f]	0.86	0.87	0.86	0.83[e]	0.03
d 7 to 14										
ADG, lb	0.72	0.72	0.73	0.74	0.71	0.75	0.69	0.73	0.69	0.04
ADFI, lb	0.75	0.78	0.78	0.81	0.78	0.81	0.77	0.82	0.76	0.04
F/G	1.05	1.07	1.08	1.09	1.10	1.07	1.11	1.12[d]	1.11	0.03
d 0 to 14										
ADG, lb[b]	0.57	0.62	0.65[e]	0.64[d]	0.62	0.66[c]	0.64[f]	0.67[c]	0.63[f]	0.03
ADFI, lb[b]	0.56	0.61	0.63[e]	0.63[c]	0.61	0.64[c]	0.63[e]	0.66[c]	0.62[f]	0.03
F/G	1.00	0.99	0.98	0.98	0.99	0.98	1.00	1.00	0.98	0.02
d 14 to 24										
ADG, lb	0.88	0.90	0.86	0.88	0.89	0.84	0.90	0.86	0.85	0.04
ADFI, lb	1.26	1.23	1.15[f]	1.21	1.19	1.17	1.24	1.20	1.19	0.05
F/G	1.44	1.38	1.34	1.40	1.35	1.39	1.39	1.40	1.42	0.07
d 0 to 24										
ADG, lb	0.70	0.74	0.74	0.74	0.73	0.73	0.75	0.75	0.72	0.03
ADFI, lb	0.85	0.87	0.85	0.87	0.85	0.86	0.89	0.89	0.86	0.03
F/G	1.22	1.18	1.15[f]	1.18	1.17	1.18	1.19	1.19	1.19	0.03
Final wt, lb	31.58	31.75	31.36	31.23	31.48	31.62	31.77	31.54	31.04	1.28

[a]A total of 360 pigs (5 pigs per pen and 8 pens per treatment) with an average initial BW of 13.8 lb.
[b]Control vs. mean of plasma treatments (P<0.05).
[c]Control vs. regular, P<0.05.
[d]Control vs. regular, P<0.10.
[e]Control vs. irradiated, P<0.05.
[f]Control vs. irradiated, P<0.10.
[g]No irradiation effect, P>0.10.

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Table 4. Chemical Analyses of Spray-Dried Animal Plasma (Exp. 2)[a]

	AP 820		Food Grade	
Item	Regular	Irradiated	Regular	Irradiated
Crude protein, %	N/A[b]	N/A[b]	N/A[b]	N/A[b]
IgG, %	17.3	17.6	15.7	15.4
Endotoxin, ng/g	N/A[b]	N/A[b]	N/A[b]	N/A[b]
Aerobic plate count, cfu/g	$> 3.0 \times 10^5$	2.0×10^2	5.6×10^3	1.0×10^2
Total coliforms, cfu/g	< 3.0	< 3.0	< 3.0	< 3.0
E. coli, cfu/g	< 3.0	< 3.0	< 3.0	< 3.0

[a]Samples collected before complete diet manufacturing.
[b]Not available at time of publishing.

Table 5. Effect of Irradiation on Various Types of Spray-Dried Animal Plasma on Growth Performance of Nursery Pigs (Exp. 2)[a]

		AP 820		Food grade		
Item	Control	Regular	Irradiated	Regular	Irradiated	SEM
Initial wt, lb	13.43	13.37	13.45	13.46	13.43	0.03
d 0 to 7						
ADG, lb[b]	0.23	0.32[c]	0.37[eh]	0.40[c]	0.43[e]	0.02
ADFI, lb[b]	0.23	0.26	0.30[eh]	0.35[c]	0.35	0.02
F/G[b]	1.03	0.81[c]	0.83[e]	0.86[c]	0.83[e]	0.03
d 7 to 14						
ADG, lb	0.77	0.72	0.81[g]	0.75	0.76	0.05
ADFI, lb	0.81	0.76	0.83[h]	0.78	0.81	0.05
F/G	1.05	1.04	1.03	1.05	1.08	0.03
d 0 to 14						
ADG, lb[b]	0.50	0.52	0.59[eg]	0.57[c]	0.59[e]	0.03
ADFI, lb	0.52	0.51	0.57[f]	0.56	0.58[f]	0.03
F/G[b]	1.04	0.97[c]	0.96[e]	0.98[c]	0.98[e]	0.02
d 14 to 24						
ADG, lb	0.92	0.88	0.96	0.94	0.91	0.05
ADFI, lb	1.23	1.08[d]	1.26[g]	1.23	1.18	0.07
F/G	1.33	1.23[d]	1.32[h]	1.32	1.30	0.04
d 0 to 24						
ADG, lb	0.69	0.67	0.74[fg]	0.73	0.73	0.03
ADFI, lb	0.81	0.75[d]	0.86[g]	0.84	0.83	0.04
F/G	1.19	1.11[c]	1.15	1.16	1.14	0.02
Final wt, lb	29.89	29.45	31.32[fg]	30.89	30.99	0.80

[a]A total of 175 pigs (5 pigs per pen and 7 pens per treatment) with an average initial BW of 13.4 lbs. All pigs were fed experimental diets from d 0 to 14, and then switched to a common phase II diet from d 14 to 24.
[b]Control vs. mean of plasma treatments (P<0.05).
[c]Control vs. regular, P<0.05.
[d]Control vs. regular, P<0.10.
[e]Control vs. irradiated, P<0.05.
[f]Control vs. irradiated, P<0.10.
[g]Irradiated vs. regular, P<0.05.
[h]Irradiated vs. regular, P<0.10.

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EFFECT OF SOURCE AND IRRADIATION OF SPRAY-DRIED ANIMAL PLASMA ON NURSERY PIG PERFORMANCE IN A COMMERCIAL FACILITY [1]

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

Summary

Weanling pigs (1,008; initially 13.5 lb and 18 ± 2 d of age) were used in a 13-d growth assay to determine the effects of irradiation of two different plasma sources on growth performance. From d 0 to 5 postweaning, pigs fed DuCoa® plasma had improved ADG and F/G compared to pigs fed AP 920 (American Proteins, Inc.). However, from d 5 to 13, pigs fed AP 920 had improved ADG and F/G compared to pigs fed DuCoa plasma. Overall, no differences in ADG, ADFI, or F/G were detected. In addition, no differences in ADG, ADFI, or F/G were detected between irradiated plasma compared its regular form. For the entire experiment, all pigs performed similarly, regardless of plasma source and whether the plasma was irradiated or not.

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

Introduction

Previous research at Kansas State University has demonstrated that irradiating spray-dried animal plasma improves pig performance during the first two weeks after weaning with the greatest response observed during the initial week postweaning. The benefit in ADG is usually due to an increase in feed intake. In addition, this improvement due to irradiation has been shown in animal plasma from different ingredient suppliers. However, the majority of the research with irradiated plasma has been conducted in university research facilities. Therefore, it was our objective to determine the effects of irradiation of animal plasma from two different ingredient suppliers on nursery pig performance in a commercial nursery facility.

Procedures

A total of 1,008 pigs (initially 13.5 lbs and 18 ± 2 d of age) was used in a 13-d growth assay. Pigs were randomly sorted into one of 48 pens (24 pens of barrows and 24 pens of gilts) with 21 pigs/pen. All pens were then weighed and pigs allotted so all pens within each block (six total) were initially the same weight. One pen of barrows and one pen of gilts consumed feed from a single fenceline feeder. Thus the experimental unit is the combined data from the two pens. Pigs were housed in a commercial nursery located in southern Minnesota.

Pigs were allotted to one of four dietary treatments that included diets containing animal plasma from American Proteins, Inc (AP 920) or DuCoa, either in its regular or irradiated form. Single lots of the plasma sources were divided equally into two portions, with one of the portions receiving an average irradiation dose of 8.0 kGy via electrical pasteurization. All pigs were budgeted 1 lb of SEW diet (6.7% plasma), and then fed a transition diet (2.5% plasma) for the remainder of the 13-d experiment. Pigs

[1]Appreciation is expressed to Damon Knobloch and Marlin Krukeberg of Holden Farms, Northfield, MN, for use of pigs and data collection; and Ernie Hanson of Hubbard Milling, Mankato, MN, for feed manufacturing.

[2]Food Animal Health and Management Center.

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were fed experimental diets containing plasma from the same treatment for the entire study. Pigs were weighed and feed disappearance measured on d 5 and 13 after weaning to determine ADG, ADFI, and F/G for the experimental period.

Data was analyzed using the GLM procedures of SAS as a randomized complete block design with pens (one barrow and one gilt) consuming feed from a single feeder as the experimental unit. Least square means were used to determine differences between treatments. Also, contrasts were used to determine plasma source and irradiation effects.

Results and Discussion

From d 0 to 5 postweaning, pigs fed DuCoa plasma had improved ($P<0.05$) ADG and F/G compared to pigs fed AP 920 with no differences in ADFI. Irradiation of plasma, regardless of source, did not influence growth performance. From d 5 to 13, pigs fed AP 920 had improved ($P<0.05$) ADG and F/G compared to pigs fed DuCoa plasma. Similar to d 0 to 5, ADFI was not influenced by plasma source and irradiation of plasma had no effect on growth performance.

Overall, no differences in ADG, ADFI, or F/G were detected between treatments as all pigs performed similarly, regardless of plasma source and whether the plasma was irradiated or not.

In conclusion, the results of this study conflict with previously reported data that indicated irradiation of animal plasma improved growth performance in nursery pigs. The improved ADG generally observed from pigs fed irradiated plasma in previous trials has been the result of increased ADFI, which did not occur in this experiment. Although differences between plasma sources were detected within the two periods, pigs performed similarly overall. Thus, least cost pricing of plasma should be used to maximize profitability without jeopardizing growth performance, and research studying the effects of nursery pigs fed irradiated plasma under commercial conditions needs further investigation.

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Table 1. Composition of Experimental Diets

Ingredient, %	SEW[a]	Transition[b]
Corn	33.65	36.63
Spray-dried whey	25.00	25.00
Soybean meal (46.5% CP)	12.53	21.37
Spray-dried animal plasma[c]	6.70	2.50
Select menhaden fish meal	6.00	6.00
Choice white grease	6.00	5.00
Lactose	5.00	-
Spray-dried blood cells	1.65	-
Medication[d]	1.00	1.00
Monocalcium phosphate (21% P)	0.75	0.75
Limestone	0.45	0.50
Zinc oxide	0.38	0.38
Vitamin/trace mineral premix	0.30	0.30
Salt	0.20	0.30
L-lysine HCl	0.15	0.15
DL-methionine	0.15	0.07
L-threonine	0.05	0.05
Choline chloride, 60%	0.05	-
Total	100.00	100.00
Calculated Analysis		
Lysine, %	1.70	1.55
Met:lysine ratio, %	30	29
Met & Cys:lysine ratio,%	56	54
Threonine:lysine ratio, %	64	65
Tryptophan:lysine ratio, %	18	18
ME, kcal/lb	1,524	1574
Crude protein, %	22.3	21.9
Calcium, %	0.97	0.92
Phosphorus, %	0.82	0.81
Available phosphorus, %	0.65	0.59
Lysine:calorie ratio, g/Mcal ME	5.06	4.47

[a]Fed for first 5 d post-weaning. [b]Fed from d 5 until d 13 post-weaning. [c]AP 920 (American Proteins, Inc., Ames, IA.) or DuCoa (Highland, IL), regular or irradiated. [d]Provided 140 g neoymicin and 140 g oxytetracycline per ton.

Table 2. Effects of Source and Irradiation of Animal Plasma on Weanling Pig Growth Performance[a]

	AP 920[b]		DuCoa[c]		
Item	Regular	Irradiated	Regular	Irradiated	SEM
d 0 to 5					
ADG, lb[d]	0.24	0.23	0.27	0.27	0.02
ADFI, lb	0.24	0.24	0.26	0.24	0.01
F/G[d]	1.07	1.09	1.02	0.95	0.04
d 5 to 13					
ADG, lb[d]	0.58	0.58	0.56	0.56	0.01
ADFI, lb	0.57	0.60	0.60	0.59	0.01
F/G[d]	0.99	1.02	1.08	1.05	0.02
d 0 to 13					
ADG, lb	0.45	0.45	0.44	0.45	0.01
ADFI, lb	0.45	0.46	0.47	0.46	0.01
F/G	0.99	1.03	1.05	1.02	0.02

[a]A total of 1,008 pigs (6 feeders/trt with 2 pens of 21 pigs per feeder, thus 42 pigs consumed feed per feeder) with an average initial BW of 13.5 lb. [b]American Proteins, Inc., Ames, IA. [c]DuCoa L. P., Highland, IL. [d]AP 920 vs. DuCoa ($P<0.05$).

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EVALUATION OF IRRADIATION AND TERMIN-8® ADDITION TO SPRAY-DRIED ANIMAL PLASMA, BASE MIX AND/OR WHOLE DIET ON GROWTH PERFORMANCE OF NURSERY PIGS

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Summary

Two studies were conducted to evaluate the effects of irradiation of spray-dried animal plasma and Termin-8® treatment to spray-dried animal plasma, base mix (specialty protein products, milk products, ground oat groats, soy flour, flow agent, vitamins, and minerals), or whole diet on nursery pig performance. Overall (d 0 to 14) in Exp. 1, pigs fed diets containing irradiated plasma had increased ADG and pigs fed Termin-8® treated plasma had increased ADG and ADFI compared to pigs fed diets with regular plasma or whole diets (containing either regular or irradiated plasma) treated with Termin-8. No differences in F/G were observed among treatments. In Exp. 2, pigs fed diets that contained either animal plasma or base mix treated with Termin-8 in the SEW diet had increased ADG and F/G from d 0 to 13 compared to no Termin-8 treatment, but no differences were observed overall (d 0 to 40). Therefore, the use of irradiated spray-dried animal plasma and Termin-8 treated spray-dried animal plasma and base mix improves growth performance in nursery pigs during the initial period after weaning.

(Key Words: Irradiation, Termin-8®, Nursery Pig.)

Introduction

We have observed improvements in growth performance of nursery pigs fed diets containing irradiated spray-dried animal blood products compared to their regular form. Irradiation of these blood products dramatically decreases the total amount of bacteria contained in the ingredient. Although not confirmed at this time, the reduction in bacteria or a deactivation of an antinutritional factor associated with these ingredients may possibly contribute to the increased growth performance. Termin-8 is an antibacterial feed additive produced by the Anitox Corporation. It contains a mixture of formaldehyde, propionic acid, d-limonene, mono- and di-glycerides of edible oils and may provide a model that can be used and as a means for reducing bacteria in feed ingredients and the entire diet. However, the effects of Termin-8 have not yet been examined in diets for nursery pigs. Therefore, our objective was to determine the effects of irradiation of spray-dried animal plasma as well as Termin-8 treatment to specialty ingredients included in a nursery base mix or the whole diet on nursery pig performance in both university and commercial research facilities.

Procedures

Experiment 1. A total of 325 pigs (BW of 12.7 lb and 17 ± 2 d of age) were blocked by weight and allotted to one of five dietary treatments. There were five pigs/pen and 13 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

[1]Food Animal Health and Management Center.
[2]The Pork Group, Inc., Rogers, AR.
[3]Nutrablend Corporation, Neosho, MO.

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waterer to provide ad libitum access to feed and water. Initial temperature was 90°F for the first 7 d, and was lowered approximately 3°F for the second week of the experiment.

Experimental diets (Table 1) were fed in meal form and formulated to contain 1.50% lysine, 0.90 Ca, and 0.80 P. Treatment diets included the following: 1) Control diet with regular spray-dried plasma; 2) Control diet with irradiated plasma; 3) Control diet with Termin-8 treated plasma; 4) Control diet with Termin-8 treatment to the whole diet; 5) Treatment 2 with Termin-8 treatment to the whole diet. Termin-8 application was provided at the FDA approved level of 6 lb/ton of total product (plasma or complete diet) and was performed by the Anitox Corporation, Lawrenceville, GA. Irradiation dosage used for the irradiated animal plasma treatments was 9.75 kGy. All individual ingredients used in the diets originated from similar lots, thus no influence of product variation should be present among treatments. Diets were formulated to meet or exceed the recommendations for all vitamins, minerals and amino acid ratios relative to lysine as set forth by the NRC (1998). Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 7 and 14. In addition, spray-dried animal plasma and diet samples were collected for bacterial analysis.

Data were analyzed through the MIXED procedures of SAS as a randomized complete block design with pen as the experimental unit. The Least Square Difference (LSD) test was utilized to determine differences among treatments ($P<0.05$), as well as to compare experimental diets vs. the control diet.

Experiment 2. A total of 1,698 pigs (BW of 11.03 lb and 17 ± 2 d of age) were used in a 40 d growth assay to determine the effect of Termin-8 treatment to either the spray-dried animal plasma or base mix portion of the SEW diet on pig performance in a commercial facility. Pigs were placed into pens by body size and allotted to one of three dietary treatments. There were 12 to 19 pigs/pen (uniform within block) and 36 pens/treatment. The trial was conducted at a commercial nursery facility at Holdenville, OK.

Diets for the entire experiment were provided in four stages. The diets (Table 2) were formulated to contain 1.67, 1.47, 1.35, and 1.24 % total lysine. Each pig was budgeted 5 and 2.5 lb of feed, respectively, for the SEW (d 0 to 10) and transition (d 10 to 13) diets, with phase II (d 13 to 28) and phase III (d 28 to 40) diets fed for the remainder of the experimental period. However, only the SEW (first phase) diet was involved in the treatment period, with all other phases (transition, phase II, and phase III) fed to determine subsequent performance. Treatment diets were formulated to identical nutrient compositions and included the following: 1) Control diet with no ingredients treated with Termin-8; 2) Control diet with Termin-8 treated spray-dried animal plasma; 3) Control diet with Termin-8 treated base mix (specialty protein products, milk products, ground oat groats, soy flour, flow agent, vitamins, and minerals). Termin-8 application was provided at the FDA approved level of 6 lb/ton of total product (plasma, base mix, or complete diet) and was performed by the Anitox Corporation, Lawrenceville, GA. Average daily gain, ADFI, and F/G were determined by weighing individual pens of pigs and calculating feed disbursement for each pen on d 8, 13, 28, and 40.

Data were analyzed through the MIXED procedures of SAS as a randomized complete block design with pen as the experimental unit. The Least Square Difference (LSD) test was utilized to determine differences among treatments ($P<0.05$). In addition, initial pig weight was used as a covariate for all analyses of growth performance and ending weights. This was used because differences in the beginning weight of pigs among treatments were detected ($P<0.05$).

Results and Discussion

Experiment 1. From d 0 to 7 (Tables 3 and 4), pigs fed diets containing irradiated plasma had increased ADG ($P<0.05$) compared to pigs fed the control diet and whole

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diets (containing either regular or irradiated plasma) treated with Termin-8, while ADFI ($P<0.05$) was improved over the latter two. In contrast, pigs fed Termin-8 treated plasma had increased ADFI ($P<0.05$) compared to the pigs fed the control and whole diets (containing either regular or irradiated plasma) treated with Termin-8, while ADG ($P<0.05$) was improved over the latter two. In addition, pigs fed the control diet tended to have increased ADFI ($P<0.09$) compared to the whole diets containing Termin-8 treatment. No differences in F/G were observed among treatments.

From d 7 to 14, pigs fed diets containing Termin-8 treated plasma had greater ADG and ADFI ($P<0.05$) then pigs fed whole diets (containing either regular or irradiated plasma) treated with Termin-8®. In addition, pigs fed diets containing Termin-8® treated plasma tended to have greater ADG ($P<0.10$) and ADFI ($P<0.13$) compared to pigs fed the control diet. Pigs fed the control diet had an improved F/G ($P<0.05$) compared to pigs fed the whole diet treated with Termin-8 that contained regular plasma.

Overall (d 0 to 14), pigs fed diets containing irradiated plasma had greater ADG ($P<0.05$) while pigs fed diets containing Termin-8 treated plasma had improved ADG and ADFI ($P<0.05$) compared to pigs fed the control and whole diets treated with Termin-8. Also, pigs fed the control diet tended ($P<0.06$) to have greater ADFI then pigs fed the whole diet treated with Termin-8 that contained regular plasma. No differences in feed efficiency were observed between dietary treatments. Furthermore, Termin-8 treatment to the whole diet did not influence growth in this study, but numerical depressions in ADFI were evident.

Irradiation of spray-dried animal plasma eliminated all detectable bacteria (Table 3), while the use of Termin-8 reduced the bacterial concentration by approximately one-half compared to non-treated spray dried animal plasma. In addition, use of Termin-8 lowered the bacterial concentrations of the total diet compared to those not treated with Termin-8.

Experiment 2. From d 0 to 8 (Table 5), pigs fed diets containing Termin-8 treated plasma or base mix had improved ADG, F/G, and d 8 weight ($P<0.01$) compared to pigs fed the control diet. In addition, pigs fed Termin-8® treated plasma gained faster and were heavier ($P<0.01$) and tended to have improved F/G ($P<0.10$) compared to those fed diets that had Termin-8 treated base mix. No differences in ADFI were observed among dietary treatments.

Pigs were budgeted 5 lb of SEW treatment diets, then switched to a common transition diet (budgeted at 2.5 lb/pig) until d 13. Because no differences in ADFI were observed among treatments, all pigs were switched to the Transition diet on d 10. No differences in ADG, ADFI, and F/G were detected between d 8 to 13. However, pigs fed diets with Termin-8 treatment to either the plasma or base mix portion of the diet were heavier ($P<0.01$) at the end of d 13 than the control pigs.

For d 13 to 28 (phase II common diet), pigs fed the control diet had improved ADG compared to pigs fed Termin-8 treated plasma ($P<0.05$) and base mix ($P<0.10$), but no differences in ADFI or F/G were observed. The reason why pigs previously fed the control diet had increased growth performance after the treatment period is currently unknown. Additionally, there were no differences in growth performance from d 28 to 40 (phase III common diet) as well as for the overall experiment (d 0 to 40). Furthermore, no differences in final body weight between treatments was observed; however, pigs fed Termin-8 treated plasma or base mix maintained the majority of the weight advantage that occurred during the treatment period.

In conclusion, as previous research has shown, the use of irradiated spray-dried animal plasma compared to its regular form improves growth performance in nursery pigs. In Exp. 1, pigs fed irradiated or Termin-8 treated spray-dried animal plasma had similar improvements in growth performance. However, Termin-8 treatment to the whole diet did not improve nursery pig performance and actually diminished the improvement seen when pigs were fed irradi-

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ated plasma. In the commercial facilities used in Exp. 2, Termin-8 application to the animal plasma or base mix stimulated growth immediately postweaning; however, the initial difference in growth performance diminished when pigs were placed on common diets for the remainder of the nursery phase. Additional studies to determine the appropriate amount of Termin-8 application to spray-dried animal plasma or whole diet need to be conducted to establish an amount that will achieve maximum growth performance in pigs. Research is also needed on how to maintain the initial advantage in growth performance over the entire nursery phase. Finally, the mode of action by which either irradiation or Termin-8 application to spray-dried animal plasma or base mix improves growth performance needs to be determined.

Table 1. Composition of Treatment Diets for Exp. 1[a]

Ingredient, %	Control	Irradiated Plasma	Termin-8 Plasma[b]	Termin-8 Whole Diet[b]	Termin-8 Whole Diet[b] with Irradiated Plasma
Corn	49.06	49.06	49.06	49.06	49.06
Soybean meal (46.5%)	25.74	25.74	25.74	25.74	25.74
Spray-dried whey	15.00	15.00	15.00	15.00	15.00
Spray-dried animal plasma	5.00	5.00	5.02	5.00	5.00
Termin-8	--	--	--	0.30	0.30
Corn starch	0.30	0.30	0.28	--	--
Medicationc[c]	1.00	1.00	1.00	1.00	1.00
Monocalcium phosphate (21% P)	1.38	1.38	1.38	1.38	1.38
Limestone	1.15	1.15	1.15	1.15	1.15
Salt	0.30	0.30	0.30	0.30	0.30
Zinc oxide	0.39	0.39	0.39	0.39	0.39
Vitamin premix	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
L-lysine HCl	0.15	0.15	0.15	0.15	0.15
Dl-methionine	0.13	0.13	0.13	0.13	0.13
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
Lysine, %	1.50	1.50	1.50	1.50	1.50
Met:lys ratio, %	30	30	30	30	30
Met & Cys:lys ratio,%	60	60	60	60	60
Threonine:lys ratio, %	64	64	64	64	64
Tryptophan:lys ratio, %	19	19	19	19	19
ME, kcal/lb	1463	1463	1463	1468	1468
Calcium, %	0.90	0.90	0.90	0.90	0.90
Phosphorus, %	0.80	0.80	0.80	0.80	0.80
Available phosphorus, %	0.46	0.46	0.46	0.46	0.46
Sodium, %	0.43	0.43	0.43	0.43	0.43
Chloride, %	0.53	0.53	0.53	0.53	0.53

[a]Experimental diets fed from d 0 to 14.
[b]Termin-8 inclusion rate of 6 lb/ton.
[c]Provided 50 g/ton carbodox.

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Table 2. Composition of Diets for Exp. 2

Ingredient, %	SEW[a]	Transition[b]	Phase II[c]	Phase III[d]
Corn	30.62	30.75	44.04	51.42
Soybean meal (46.5%)	15.00	22.49	29.65	36.39
SEW premix[f]	47.00	--	--	--
Transition premix[g]	--	38.48	--	--
Phase II premix[h]	--	--	17.00	--
Bakery meal by-product	--	--	2.50	5.00
Poultry fat	5.00	--	--	--
Animal & vegetable fat	--	4.95	4.35	4.65
Medication[e]	0.20	1.00	0.50	0.12
Monocalcium phosphate (21% P)	1.10	1.70	1.60	1.70
Limestone	0.45	0.05	--	0.30
Salt	0.20	0.22	0.10	0.13
Copper sulfate	--	--	--	0.07
Vitamin premix	--	--	--	0.10
Trace mineral premix	--	--	--	0.10
L-Lysine	0.21	0.19	0.16	--
MHA-Alimet	0.22	0.17	0.10	0.01
L-Threonine	--	--	--	0.01
Total	100.00	100.00	100.00	100.00
Calculated Analysis				
Lysine, %	1.67	1.47	1.35	1.24
Met:lys, ratio, %	0.29	0.31	0.30	0.29
Met & Cys:lys ratio,%	0.59	0.57	0.57	0.60
Threonine:lys ratio, %	0.62	0.68	0.60	0.68
Tryptophan:lys ratio, %	0.18	0.21	0.19	0.22
ME, kcal/lb	1532	1525	1579	1580
Calcium, %	0.90	0.83	0.71	0.78
Phosphorus %	0.74	0.75	0.70	0.61
Available phosphorus, %	0.60	0.65	0.38	0.42
Sodium, %	0.63	0.58	0.26	0.19
Chloride, %	0.61	.59	0.15	0.16

[a]Experimental diet fed from d 0 to 10.
[b]Common diet feed from d 10 to 13.
[c]Common diet fed from d 13 to 28.
[d]Common diet fed from d 28 to 40.
[e]Provided 360 g/ton of tilmicosin for the SEW, transition, and phase II, while tylosin provided 100 g/ton in phase III.
[f]Included animal plasma, red blood cells, dried whey, lactose, ground oat groats, soy flour, flow agent, red iron oxide, zinc oxide, and trace mineral and vitamin premixes.
[g]Included animal plasma, red blood cells, dried whey, ground oat groats, flow agent, zinc oxide, and trace mineral and vitamin premixes.
[h]Included red blood cells, dried whey, zinc oxide, black iron oxide, and trace mineral and vitamin premixes.

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Table 3. Effects of Irradiation or Termin-8 Treatment of Plasma and/or Whole Diet on Weanling Pig Growth Performance[a]

Item	Control	Irradiated plasma	Termin-8 Plasma[b]	Termin-8 Whole Diet[b]	Termin-8 Whole Diet[b] with Irradiated Plasma	SEM
d 0 to 7						
ADG, lb	0.34[ce]	0.43[d]	0.41[cd]	0.29[e]	0.31[e]	0.030
ADFI, lb	0.39[ce]	0.43[cd]	0.47[d]	0.33[e]	0.33[e]	0.026
F/G	1.14	1.03	1.17	1.06	1.11	0.089
d 7 to 14						
ADG, lb	0.70[cd]	0.75[cd]	0.77[c]	0.67[d]	0.69[d]	0.036
ADFI, lb	0.85[cde]	0.89[cd]	0.93[c]	0.77[e]	0.80[de]	0.039
F/G	1.24[c]	1.19[cd]	1.22[cd]	1.14[d]	1.18[cd]	0.041
d 0 to 14						
ADG, lb	0.52[e]	0.59[d]	0.59[d]	0.48[e]	0.50[e]	0.027
ADFI, lb	0.62[de]	0.66[cd]	0.70[c]	0.55[e]	0.56[e]	0.029
F/G	1.20	1.12	1.20	1.14	1.14	0.068
Aerobic Plate Count						
Plasma, CFU/g	1.8×10^5	0	9.1×10^4	1.8×10^5	0	
Whole diet, CFU/g	4.8×10^4	5.0×10^4	6.3×10^4	6.5×10^3	1.1×10^4	

[a]A total of 325 pigs (five pigs per pen and 13 pens per treatment) with an average initial BW of 12.7 lb.
[b]Termin-8 inclusion rate of 6 lb/ton of plasma or whole diet.
[cde]Means in same row with different superscripts differ ($P<0.05$).

Table 4. Probability of Irradiation or Termin-8 Treatment of Plasma and/or Whole Diet on Weanling Pig Growth Performance[a]

	Treatment Diet vs. Control				
Item	Irradiated Plasma	Termin-8 Plasma[b]	Termin-8 Whole Diet[b]	Termin-8 Whole Diet[b] with Irradiated Plasma	SEM
d 0 to 7					
ADG, lb	0.03	0.11	0.20	0.39	0.030
ADFI, lb	0.20	0.02	0.09	0.09	0.026
F/G	0.36	0.81	0.51	0.85	0.089
d 7 to 14					
ADG, lb	0.19	0.10	0.58	0.86	0.036
ADFI, lb	0.50	0.13	0.08	0.30	0.039
F/G	0.29	0.67	0.05	0.21	0.041
d 0 to 14					
ADG, lb	0.04	0.05	0.28	0.54	0.027
ADFI, lb	0.30	0.04	0.06	0.14	0.029
F/G	0.39	0.97	0.52	0.54	0.068

[a]A total of 325 pigs (five pigs per pen and 13 pens per treatment) with an average initial BW of 12.7 lb.
[b]Termin-8 inclusion rate of 6 lb/ton of plasma or whole diet.

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Table 5. Effects of Termin-8 on Growth Performance in Weanling Pigs[a,b]

		Termin-8 Application		
Item	Control	Plasma	Base Mix	SEM[c]
Initial wt[dg]	10.80	11.17	11.13	0.13
d 0 to 8				
ADG, lb[fhi]	0.38	0.49	0.45	0.01
ADFI, lb	0.39	0.40	0.41	0.01
F/G[fhj]	1.05	0.84	0.92	0.03
d 8 wt[fhi]	14.05	15.00	14.66	0.08
d 8 to 13				
ADG, lb	0.66	0.65	0.69	0.03
ADFI, lb	0.86	0.87	0.87	0.03
F/G	1.35	1.39	1.30	0.08
d 0 to 13				
ADG, lb[fg]	0.48	0.55	0.54	0.01
ADFI, lb	0.57	0.58	0.58	0.02
F/G[eg]	1.19	1.05	1.07	0.05
d 13 wt, lb[fh]	17.33	18.35	18.13	0.14
d 13 to 28				
ADG, lb[dg]	0.77	0.73	0.73	0.02
ADFI, lb	1.27	1.26	1.24	0.02
F/G	1.68	1.77	1.72	0.05
d 28 to 40				
ADG, lb	1.09	1.10	1.13	0.02
ADFI, lb	2.04	2.01	2.06	0.04
F/G	1.88	1.85	1.84	0.04
d 13 to 40				
ADG, lb	0.92	0.90	0.92	0.01
ADFI, lb	1.62	1.60	1.61	0.02
F/G	1.76	1.79	1.77	0.03
d 0 to 40				
ADG	0.77	0.78	0.79	0.01
ADFI	1.25	1.26	1.27	0.02
F/G	1.63	1.61	1.62	0.02
d 40 wt, lb	41.56	42.16	42.23	0.30

[a]A total of 1698 pigs with 12 to 19 pigs/ pen (uniform within block) and 36 pens/treatment with an avg initial BW of 11.03 lb.

[b]Pigs were budgeted 5 lb of SEW diet, which contained either no Termin-8, only plasma treated with Termin-8, or the entire base mix (specialty protein products, milk products, vitamins, and minerals) treated with Termin-8. Pigs were then fed a common transition, phase II (d 13 to 28), and phase III (d 28 to 40) diets for the remainder of the experimental period.

[c]Initial wt used as a covariate for growth performance and ending wt.

[d]Control vs. base mix with Termin-8 treatment ($P<0.10$).

[e]Control vs. base mix with Termin-8 treatment ($P<0.05$).

[f]Control vs. base mix with Termin-8 treatment ($P<0.01$).

[g]Control vs. plasma with Termin-8 treatment ($P<0.05$).

[h]Control vs. plasma with Termin-8 treatment ($P<0.01$).

[i]Base mix vs. plasma Termin-8 treatment ($P<0.01$).

[j]Base mix vs. plasma Termin-8 treatment ($P<0.10$).

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EFFECTS OF INGREDIENT AND WHOLE DIET IRRADIATION ON NURSERY PIG PERFORMANCE

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Summary

Two trials were conducted to determine the effects of irradiation of individual ingredients or the whole diet on growth performance in nursery pigs. The response was similar for both trials with pigs fed diets containing irradiated spray-dried animal plasma or soybean meal having increased (P<0.05) ADG compared with pigs fed the control diet with no irradiated ingredients or the complete diet that was irradiated. Also, ADFI (P<0.05) was higher for pigs consuming the diet with irradiated soybean meal compared with those fed the irradiated whole diet. Pigs fed irradiated spray-dried animal plasma also had superior F/G (P<0.05) compared with those fed diets containing irradiated microingredients or if all ingredients had been irradiated before manufacturing. Therefore, irradiation of certain feed ingredients can improve growth performance in nursery, whereas irradiation of all ingredients in the diet or the whole diet does not enhance performance.

(Key Words: Nursery Pig, Feed Ingredients, Irradiation.)

Introduction

Research has established that irradiation of dried blood products before adding them to diets for nursery pigs improves growth performance compared with dried blood products that have not been irradiated. However, irradiation of other protein, carbohydrate, energy, and microingredient sources used in nursery pig diets has not been thoroughly researched. Irradiation of other ingredients that are typically included in nursery diets may enhance growth performance similar to that of dried blood products. Therefore, it was our objective to determine the effects of irradiation of individual ingredients or the whole diet on nursery pig performance.

Procedures

Two experiments were conducted to determine the effects of irradiation of individual ingredients or the whole diet on growth performance in nursery pigs. In Exp. 1, 400 pigs (BW of 10.8 lb and 15 ± 2 d of age) were used in a 14-d growth assay. In Exp. 2, 480 pigs (BW of 11.3 lb and 15 ± 2 d of age) were used in a 12-d growth assay. Pigs were blocked by weight and allotted to one of 10 dietary treatments in both experiments. In Exp. 1, there were eight pigs/pen and five pens/treatment, whereas there were eight pigs/pen and six pens/treatment in Exp 2. For both experiments, pigs were housed in an environmentally controlled nursery in 5 × 5 ft pens on a commercial farm in N.E. Kansas. All pens contained one self-feeder and two nipple waterers to provide ad libitum access to feed and water.

All diets were fed in pelleted form, and pigs were assigned to one of 10 dietary treatments. First, a control diet was used containing ingredients that were not irradiated. Other treatments included diets that had specific ingredients irradiated, which included corn, soybean meal, whey,

[1]Food Animal Health and Management Center.

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animal plasma, fishmeal, soybean oil, all microingredients combined (antibiotic, salt, monocalcium phosphate, limestone, zinc oxide, vitamin and trace mineral premixes, and DL-methionine). Finally, a diet including all ingredients that had been irradiated and a diet that was manufactured and subsequently irradiated were utilized. All irradiated ingredients and complete feed were exposed to an average irradiation dose of 8.5 kGy from gamma ray (colbalt-60 source) irradiation in Exp. 1 and electron beam irradiation in Exp. 2. The diet used in this experiment was formulated to contain 1.50% lysine, 0.90 Ca, and 0.50 available P. For Exp. 1, ADG, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 7 and 14, while in Exp. 2 this was accomplished on d 6 and 12. Data for both experiments was pooled and analyzed using the GLM procedure of SAS as a randomized complete block design with pen as the experimental unit. Phase I data represents means from d 0 to 7 of Exp. 1 and d 0 to 6 of Exp. 2, while Phase II data represents means from d 7 to 14 for Exp. 1 and d 6 to 12 for Exp. 2.

Results

Irradiation of individual feed ingredients and the complete diet proved to be successful in reducing the total aerobic bacteria concentrations (Table 2). Bacteria levels in regular plasma and corn were noticeably the highest with minimal concentrations detected in spray-dried whey and soybean oil. Reductions in total bacterial concentrations in diets that had individual ingredients irradiated were minimal compared with the control diet, but if all ingredients or the entire diet had undergone irradiation treatment the bacterial concentration was substantially reduced (Table 3).

For Phase I, nursery pigs fed diets containing either irradiated soybean meal or spray-dried animal plasma had improved ($P<0.05$) ADG while pigs fed irradiated corn tended ($P<0.07$) to have increased ADG compared with pigs fed the control diet (Table 4). In addition, pigs fed irradiated corn, soybean meal, or spray-dried animal plasma had increased ADFI ($P<0.05$) compared with pigs fed the diet that was manufactured and subsequently irradiated. Also, pigs fed diets containing irradiated soybean meal, spray-dried animal plasma, or the diet that was manufactured and then irradiated had improved F/G ($P<0.05$) compared with the control diet with no irradiated ingredients, while those fed irradiated fishmeal, soybean oil, or the diet with all ingredients irradiated tended ($P<0.08$) to do the same.

Table 1. Composition of Diet (As Fed Basis)

Ingredient	%
Corn	38.98
Soybean meal (46.5%)	15.72
Spray-dried whey	25.00
Spray-dried animal plasma	6.00
Select menhaden fish meal	6.00
Soybean oil	5.00
Medication[a]	1.00
Monocalcium phosphate (21% P)	0.57
Limestone	0.60
Zinc oxide	0.39
Vitamin premix	0.25
Salt	0.25
Trace mineral premix	0.15
DL-methionine	0.09
Total	100.00
Calculated Analysis	
Lysine, %	1.50
Met:lysine ratio, %	30
Met & Cys:lysine ratio,%	60
Threonine:lysine ratio, %	68
Tryptophan:lysine ratio, %	19
ME, kcal/lb	1,595
Protein, %	22.1
Calcium, %	0.90
Phosphorus, %	0.80
Available phosphorus, %	0.50

[a]Provided 50 g per ton carbadox.

For Phase II, ADG and ADFI were not affected by dietary treatment, but F/G was improved ($P<0.05$) for pigs consuming diets with irradiated spray-dried animal plasma compared with those fed the diet with all ingredients irradiated.

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Overall, ADG was increased ($P<0.05$) for pigs fed the diet with irradiated spray-dried animal plasma compared with those fed either the control, the diet containing irradiated microingredients, or the diet that was manufactured and subsequently irradiated. Also, pigs fed irradiated soybean meal had increased ($P<0.05$) ADFI compared with the manufactured diet that was irradiated and tended to improve ADFI ($P<0.07$) compared with those fed the control. In addition, pigs feed irradiated spray-dried animal plasma had improved ($P<0.05$) F/G compared with those fed the diet with all ingredients irradiated. Furthermore, they had a moderate increase ($P<0.06$) in efficiency of gain compared with pigs fed the control. Finally, the addition of irradiated corn, whey, fishmeal, soybean oil, microingredients, or if all ingredients or whole diet was irradiated did not influence growth performance ($P>0.12$) compared with the control for any of the growth parameters measured in this study.

In conclusion, the bacteria concentration of ingredients commonly used in nursery pig diets was reduced when subjected to irradiation treatment. Bacterial concentration of ingredients varied greatly with highest levels measured in spray-dried animal plasma, corn, and soybean meal and the lowest levels cultured in spray-dried whey and soybean oil. Use of irradiation on individual ingredients improved performance in certain instances, but no uniform pattern was detected in regards to the total aerobic bacterial concentrations in each ingredient. Although the largest improvements in growth performance were elicited from two of the irradiated protein sources (spray-dried animal plasma and soybean meal) used in this study, the benefits from irradiating these ingredients were lost when all ingredients or whole diet was irradiated compared with the inclusion of each ingredient individually. The reasons for this loss of improvement is not currently known, and further research needs to be conducted to determine why certain ingredients that are irradiated improve growth performance.

Table 2. Aerobic Bacteria Concentration of Feed Ingredients[a]

	Total Plate Count, CFU/g		Total Coliform Count, CFU/g	
Ingredient	Regular	Irradiated[a]	Regular	Irradiated[a]
Corn	1.4×10^5	1.3×10^2	6.8×10^4	1.0×10^1
Soybean meal (46.5%)	4.1×10^4	8.5×10^1	5.7×10^2	0
Spray-dried whey	2.3×10^2	9.0×10^1	0	0
Spray-dried animal plasma	4.1×10^5	8.0×10^1	0	0
Select menhaden fish meal	1.5×10^3	4.0×10^2	0	0
Soybean oil	1.5×10^2	1.2×10^1	0	0
Micronutrients[b]	3.2×10^3	1.4×10^2	$2.1\ 6 \times 10^2$	0

[a]Irradiated at an average dose of 8.5 kGy.
[b]Medication, monocalcium phosphate (21% P), limestone, zinc oxide, vitamin and trace mineral premixes, salt, and DL-methionine.

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Table 3. Aerobic Bacteria Concentrations of Manufactured Diets[a]

		Portion of Diet Treated with Irradiation Prior to Manufacturing								
Item	Control	Corn	SB Meal	Whey	Plasma	Fishmeal	SB Oil	Micro's[b]	All	Complete[c]
Total Plate Count	5.1×10^4	1.4×10^4	1.3×10^4	2.6×10^4	2.2×10^4	9.1×10^4	4.2×10^3	1.2×10^3	8.9×10^2	4.5×10^2
Total Coliform Count	3.0×10^3	8.0×10^2	4.4×10^3	3.0×10^3	1.0×10^2	5.5×10^3	1.7×10^2	2.0×10^1	2.0×10^2	2.0×10^2

[a]Irradiated at an average dose of 8.5 kGy.
[b]Medication, monocalcium phosphate (21% P), limestone, zinc oxide, vitamin and trace mineral premixes, salt, and DL-methionine.

Table 4. Effects of Irradiation of Ingredients and Whole Diet on Nursery Pig Performance[a]

		Portion of Diet Treated with Irradiation Prior to Manufacturing									
Item	Control	Corn	SB Meal	Whey	Plasma	Fishmeal	SB Oil	Micro's[b]	All	Complete[c]	SEM
Phase I[d]											
ADG, lb	0.35^{f}	0.40^{fg}	0.41^{g}	0.38^{fg}	0.41^{g}	0.39^{fg}	0.38^{fg}	0.36^{fg}	0.40^{fg}	0.36^{fg}	0.022
ADFI, lb	0.40^{fg}	0.44^{f}	0.44^{f}	0.43^{fg}	0.44^{f}	0.43^{fg}	0.42^{fg}	0.40^{fg}	0.43^{fg}	0.38^{g}	0.019
F/G	1.17^{f}	1.13^{fg}	1.07^{g}	1.12^{fg}	1.07^{g}	1.09^{fg}	1.10^{fg}	1.12^{fg}	1.09^{dg}	1.07^{g}	0.035
Phase II[e]											
ADG, lb	0.63	0.63	0.67	0.67	0.68	0.63	0.65	0.63	0.62	0.64	0.024
ADFI, lb	0.79	0.82	0.85	0.83	0.83	0.79	0.82	0.83	0.83	0.80	0.024
F/G	1.30^{fg}	1.33^{gf}	1.28^{fg}	1.28^{fg}	1.25f	1.27^{fg}	1.30^{fg}	1.33^{fg}	1.36^{g}	1.30^{fg}	0.036
Overall											
ADG, lb	0.49^{h}	0.52^{fgh}	0.54^{fg}	0.53^{fgh}	0.55^{f}	0.51^{fgh}	0.51^{fgh}	0.50^{gh}	0.51^{fgh}	0.50^{h}	0.017
ADFI, lb	0.60^{fg}	0.63^{fg}	0.64^{f}	0.63^{fg}	0.64^{fg}	0.61^{fg}	0.62^{fg}	0.62^{fg}	0.63^{fg}	0.59^{g}	0.018
F/G	1.24^{fg}	1.22^{fg}	1.19^{fg}	1.21^{fg}	1.17^{f}	1.20^{fg}	1.22^{fg}	1.25^{g}	1.25^{g}	1.20^{fg}	0.025

[a]Values are representative of two trials. Trial I had a total of 400 pigs (8 pigs per pen and five pens per treatment) with an average initial BW of 10.8 lb. Trial 2 had 480 pigs (8 pigs per pen and six pens per treatment) with an average initial BW of 11.3 lb. [b]Antibiotic, salt, monocalcium phosphate, limestone, zinc oxide, vitamin and trace mineral premixes, and DL-methionine. [c]Complete diet manufactured then irradiated. [d]Phase I is from d 0 to 7 in Trial 1 and d 0 to 6 in Trial 2. [e]Phase II is from d 7 to 14 in Trial 1 and d 6 to 12 in Trial 2. [f,g,h]Means in same row with superscripts differ ($P<0.05$).

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Table 5. Probability of Irradiation of Ingredients and Whole Diet Versus Control on Nursery Pig Performance[a]

	Portion of Diet Treated with Irradiation Prior to Manufacturing vs. Control Diet									
Item	Corn	SB Meal	Whey	Plasma	Fish Meal	SB Oil	Micro's[b]	All	Complete[c]	SEM
Phase I[d]										
ADG, lb	0.07	0.03	0.22	0.03	0.13	0.15	0.62	0.11	0.67	0.022
ADFI, lb	0.14	0.16	0.33	0.15	0.31	0.60	0.90	0.37	0.40	0.019
F/G	0.33	0.04	0.24	0.03	0.08	0.06	0.29	0.07	0.04	0.035
Phase II[e]										
ADG, lb	0.98	0.22	0.30	0.15	0.99	0.33	0.95	0.72	0.86	0.024
ADFI, lb	0.37	0.12	0.26	0.25	0.96	0.40	0.27	0.28	0.81	0.024
F/G	0.48	0.74	0.71	0.33	0.57	0.69	0.52	0.21	0.98	0.036
Overall										
ADG, lb	0.23	0.02	0.12	0.02	0.30	0.20	0.71	0.43	0.69	0.017
ADFI, lb	0.17	0.07	0.20	0.12	0.61	0.39	0.49	0.22	0.77	0.018
F/G	0.71	0.22	0.37	0.06	0.25	0.19	0.78	0.73	0.27	0.025

[a]Values are representative of two trials. Trial 1 had 400 pigs (8 pigs per pen and five pens per treatment) with an average initial BW of 10.8 lb. Trial 2 had 480 pigs (8 pigs per pen and six pens per treatment) with an average initial BW of 11.3 lb.
[b]Antibiotic, salt, monocalcium phosphate, limestone, zinc oxide, vitamin and trace mineral premixes, and DL-methionine.
[c]Complete diet manufactured then irradiated.
[d]Phase I is from d 0 to 7 in Trial 1 and d 0 to 6 in Trial 2.
[e]Phase II is from d 7 to 14 in Trial 1 and d 6 to 12 in Trial 2.

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EVALUATING CLOVES AS A POTENTIAL SUBSTITUTE FOR ANTIMICROBIALS IN NURSERY PIG DIETS [1]

R. G. Main, J. E. Minton, S. S. Dritz [2], M. D. Tokach, R. D. Goodband, and J. L. Nelssen

Summary

We conducted two trials to evaluate the effects of feeding graded levels of cloves to weanling pigs as a substitute for antimicrobials. In the first trial, improvements in ADG were observed in pigs fed the lowest level of clove addition (0.5%) and for those fed carbadox (50 g/ton). The higher levels of clove inclusion (1.0% and 2.0%) tended to reduce feed intake. A second trial was conducted evaluating performance of pigs fed diets containing 0.125%, 0.25% and 0.5% cloves (a different batch than used in trial 1). The was no ADG improvement from added cloves as was observed in the first trial, and the higher clove concentrations tended to reduce feed intake. The inconsistent response to added cloves between our two studies merits further investigation.

(Key Words: Clove, Spice, Antimicrobials.)

Introduction

Public concern over the routine use of in-feed antimicrobials continues to escalate. These issues are due to concerns that routine use of these antimicrobials contributes to antibiotic resistance in humans. Cloves and other spices have long been utilized as food preservatives. Many spices including cloves have significant antimicrobial activity. These established facts have prompted researchers to investigate the potential of using spices as substitutes for traditional antimicrobials in animal feeds. Therefore, our objective was to determine the effects of feeding graded levels of cloves to weanling pigs as a possible substitute for traditional antimicrobials.

Procedures

A total of 150 weanling pigs (averaging 13.9 lb in both studies) were used in each study. Pigs (PIC C22 × 326) were blocked by initial weight, and randomly allotted to one of the five dietary treatments in a randomized complete block design. Each pen contained 5 pigs, and each trial included 6 replicates (pens) per treatment.

Experimental diets were fed in meal form, and in two phases. Phase 1 diets were fed from d 0 to 7, and phase 2 diets were fed from d 7 to 28. Diets were formulated to contain 1.55 % and 1.40 % total dietary lysine for phases 1 and 2, respectively (Table 1). Dietary energy, lysine, mineral, and vitamin levels were held constant across treatments within each dietary phase, and across trials. In the experimental diets, clove or the feed antimicrobial replaced cornstarch.

Dietary treatments in Trial 1 included a negative control (no antimicrobial or cloves), a positive control (carbadox, 50 g/ton), and three levels of cloves (0.5, 1.0, and 2.0%). Trial 2 was completed with a similar treatment structure, but had clove inclusions of 0.125%, 0.25% and 0.5%. In addition, the cloves in this trial were obtained from a different lot than used in Trial 1.

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[1]Appreciation is expressed to Joan Pinkas and McCormick & Co., Inc. for supplying the cloves used in these evaluations.

[2]Food Animal Health and Management Center.

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

Item	Phase 1 Basal Diet	Phase 2 Basal Diet
Corn	47.21%	51.59%
Soybean meal (46.5%)	27.56%	31.51%
Monocalcium phosphate (21% P)	1.20%	1.70%
Limestone	0.95%	0.85%
Salt	0.35%	0.35%
Vitamin premix	0.25%	0.25%
Trace mineral premix	0.15%	0.15%
Sow add pack	0.05%	0.05%
Corn starch	2.00%	2.00%
L-threonine	0.00%	0.05%
Cloves	0.00%	0.00%
Carbadox	0.00%	0.00%
Lysine HCl	0.15%	0.15%
DL-methionine	0.13%	0.10%
Spray-dried porcine plasma	5.00%	1.25%
Spray dried whey	15.00%	10.00%

[a]Clove or carbadox was provided at the expense of cornstarch to provide the clove or positive control diets.

Pigs were weighed and feed disappearance was measured weekly to determine ADG, ADFI, and F/G. Data were analyzed using GLM procedures of SAS in a randomized complete block design.

Results and Discussion

In trial 1 from d 0 to 21, ADG was improved ($P<0.05$) for the pigs fed the diet containing carbadox and the diet containing 0.5% cloves compared to those fed the negative control (Table 2). For the overall d 0 to 28 period, pigs fed 0.5% cloves tended ($P<.12$) to have better ADG and d 28 average weights compared to those fed the negative control diet. Pigs fed carbadox had increased ($P<0.04$) ADG, ADFI, and day 28 average weight compared to the negative control pigs for the overall 28-day evaluation.

Average daily gain, ADFI, and 28-day average weights decreased ($P=0.05$) in pigs fed the 2.0% clove diet compared to pigs fed either the positive or negative control diets. The reduction in feed intake at the higher levels of dietary clove inclusion may have been due to the flavors associated with cloves.

Because improvements in ADG were observed through d 21for the pigs fed the 0.5% clove treatment, we conducted a second trial with a similar design but lower levels of added cloves. Additionally, we wanted to confirm the positive response observed in pigs fed 0.5% cloves.

In trial 2, pigs fed any of the added clove treatments (0.125%, 0.25%, or 0.5%) had similar ADG, ADFI, and 28-day weights compared to those fed the negative control diet (no in-feed antimicrobial). In fact, ADFI was decreased ($P<0.05$) for the d 0 to 21 period, and tended to be decreased ($P<0.09$) for pigs fed the 0.25% and 0.5% dietary clove treatments compared to pigs fed the negative control diet. Average daily gain and the 21 d average weight were improved ($P<0.05$) for pigs fed the positive control containing carbadox compared to the negative control. However, due to the growth rate in the last 7 d of the trial, there was no improvement ($P>0.63$) for the d 0 to 28 d period for the pigs fed the positive control compared to those fed the negative control diet.

Pigs fed the positive control diet containing carbadox (50 g/ton) demonstrated im-

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provement in ADG from d 0 to 21 in both trials. However, this improvement was not maintained through 28 days in the second trial. Interestingly, F/G differences were not observed between pigs fed the antimicrobial containing positive and negative control treatments in either trial. The improvements in ADG from d 0 to 21for the pigs fed the 0.5% dietary clove treatment in the initial trial were not repeated in the second evaluation. The lack of repeatability is not understood at this time.

In conclusion, substituting graded levels of cloves provided inconsistent results from d 0 to 21 post-weaning, and no benefits through 28 days after weaning. Further research is warranted to evaluate the factor(s) in spices such as cloves that may affect pig growth performance.

Table 2. Growth Performance Effects of Feeding Cloves Post-Weaning (Trial 1 Data)

	Control		Clove, %			
Item	Negative[d]	Positive[e]	0.5	1.0	2.0	SEM
d 0 to 21						
ADG, lb	0.73[a]	0.83[b]	0.82[b]	0.74[a,b]	0.66[a]	0.03
ADFI, lb	0.97[b,c]	1.06[c]	1.03[c]	0.88[a,b]	0.83[a]	0.03
F/G	1.33	1.28	1.25	1.26	1.26	0.02
d 0 to 28						
ADG	0.90[b]	0.99[c]	0.97[b,c]	0.89[a,b]	0.83[a]	0.03
ADFI	1.22[b]	1.32[c]	1.27[b,c]	1.19[b]	1.09[a]	0.03
F/G	1.35	1.33	1.32	1.33	1.33	0.02
Avg. Weight, lb						
d 0	13.9	13.9	13.9	13.9	13.9	0.03
d 21	29.2[a,b]	31.3[c]	31.1[b,c]	29.3[a,b]	27.8[a]	0.67
d 28	39.2[b]	41.7[c]	40.9[b.c]	38.9[a,b]	37.04[a]	0.75

[a,b,c]Means in the same row without a common superscript letter differ (P<0.05).
[d]No in-feed antimicrobial.
[e]Contained 55 ppm carbadox (Mecadox).

Table 3. Growth Performance Effects of Feeding Cloves Post-Weaning (Trial 2 Data)

	Control		Clove, %			
Item	Negative[c]	Positive[d]	0.125	0.25	0.50	SEM
d 0 to 21						
ADG, lb	0.74[a]	0.81[b]	0.75[a,b]	0.69[a]	0.73[a]	0.023
ADFI, lb	0.98[a]	1.00[a]	0.95[a,b]	0.87[b]	0.89[b]	0.030
F/G	1.34	1.24	1.27	1.27	1.23	0.030
d 0 to 28						
ADG, lb	0.91[a,b]	0.94[a]	0.91[a,b]	0.85[b]	0.87[b]	0.022
ADFI, lb	1.27[a,b]	1.29[a]	1.24[a,b]	1.15[b]	1.18[b]	0.034
F/G	1.39	1.37	1.36	1.36	1.35	0.023
Weight, lb						
d 0	13.9	13.9	13.9	13.9	13.9	0.02
d 21	29.4[b]	30.8[a]	29.6[a,b]	28.4[b]	29.2[b]	0.47
d 28	39.4[a,b]	40.3[a]	39.3[a,b]	37.6[b]	38.3[b]	0.61

[a,b]Means in the same row without a common superscript letter differ (P<0.05).
[c]No in-feed antimicrobial.
[d]Contained 55 ppm carbadox (Mecadox).

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COMPARISON OF INTERNATIONAL PROTEIN CORPORATION 740 FISH MEAL AND SPECIAL SELECT™ MENHADEN FISH MEAL IN NURSERY PIG DIETS

M. G. Young, M. D. Tokach, R. D. Goodband, J. L. Nelssen, S. S. Dritz, and M. Cici

Summary

One hundred and seventy five pigs (initially weighing 14.1 lb and 17 ± 2 d of age) were used in a 21-d growth assay to compare performance of pigs fed two sources of Menhaden fish meal. Overall, there was no difference in growth performance between the two fish meal sources. For the first 14 days ADG and F/G were improved by including fish meal in the diet and as the level increased from 2.5 to 5%. However, in the third week (day 14 to 21) of the trial there was no benefit in adding fish meal to the diet. These results indicate that IPC 740 fish meal can be an effective replacement for Special Select™ Menhaden fish meal in nursery diets.

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

Introduction

Switching nutrient sources from milk to complex carbohydrates, proteins, and fats often causes a reduction in performance as a result of low food intake and poor digestion. Fish meal is traditionally recognized as a digestible protein source with a high content of amino acids that help stimulate feed intake. However, the quality of fish meal varies depending on the type and species of fish, the freshness of the fish before processing, and the processing of the meal. Evaluation of the nutritional value of the fish meal from different sources and different processing will improve the accuracy with which fish meal is added to young pigs' diets.

Select Menhaden fish meal is currently considered a high quality protein source for nursery pig diets. "Special Select™" menhaden fish meal is a common source used in starter diets in the U.S. If additional sources of fish meal were found to be as effective as Special Select™, this would provide other options for feed manufacturers and producers in diet formulations. Therefore, our objective was to compare the effects of increasing levels of IPC 740 (International Proteins Corporation, St. Paul, MN) and Special Select™ Menhaden (Omega Proteins, Hammond, LA) fish meals in starter diets.

Procedures

A total of 175 pigs (initially 14.1 lb and 17 ± 2 d of age) were blocked by weight and allotted to one of five dietary treatments. There were five pigs/pen and seven pens/treatment. Pigs were housed at the Kansas State University Segregated Early Weaning Facility. Each pen was 4 × 4 ft and contained one self-feeder and one nipple waterer to provide ad libitum access to feed and water.

All pigs were fed a common segregated early weaning (SEW) diet in pellet form, for four days after weaning before going on dietary treatments. Dietary treatments were fed in meal form. Diets were formulated to contain 1.40% lysine, 0.84% Ca and 0.49% available phosphorous. In addition, 10% spray dried whey, 3% soybean oil and 0.13% crystalline lysine were added to all treatment diets. The ratio of methionine & cysteine and threonine to lysine were held constant at 57 and 63%, respectively. There were 5 experimental diets with a control diet and increasing fish meal (2.5 or 5%) from two fish meal sources (International Proteins Corporation and Omega). The fish meal partially replaced

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soybean meal as a protein source in the diets. Samples of both fish meal sources were analyzed for protein, amino acids, calcium and phosphorous (Table 2). Average daily gain (ADG), ADFI and feed efficiency were determined by weighing pigs and measuring feed disappearance on day 7, 14 and 21 of the trial (Table 3).

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 done using the GLM procedure of SAS.

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

	Fish Meal, %		
Ingredient, %	0	2.5	5.0
Corn	46.25	48.40	50.56
Soybean meal (46.5%)	36.14	31.98	27.81
Soybean oil	3.00	3.00	3.00
Monocalcium phosphate (21% P)	1.65	1.33	1.00
Limestone	0.85	0.70	0.55
Salt	0.25	0.25	0.25
Vitamin premix	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15
Mecadox	1.00	1.00	1.00
Zinc oxide	0.25	0.25	0.25
Lysine HCl	0.13	0.13	0.13
DL-methionine	0.08	0.07	0.06
Fish meal[a]	0.00	2.50	5.00
Spray dried whey	10.00	10.00	10.00
Total	100.00	100.00	100.00
Calculated Analysis			
Lysine, %	1.40	1.40	1.40
Isoleucine:lysine ration, %	68	66	65
Leucine:lysine ratio, %	135	134	132
Methionine:lysine ratio, %	30	31	31
Met & Cys:lysine ratio, %	57	57	57
Threoine:lysine ratio, %	62	62	62
Tryptophan:lysine ratio, %	20	19	19
Valine:lysine ratio, %	76	75	74
ME, kcal/lb	1525	1532	1540
Protein, %	21.9	21.8	21.6
Calcium, %	0.84	0.84	0.84
Phosphorus, %	0.80	0.78	0.77
Available phosphorus, %	0.49	0.49	0.49
Lysine:calorie ratio, g/mcal	4.17	4.14	4.12

[a]IPC 740 or Special Select™ fish meal.

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Results and Discussion

The analyzed essential amino acids were slightly higher in the IPC fish meal compared to the Special Select™ Menhaden fish meal (Table 2). Expected lysine concentrations for Menhaden fish meals as listed in the NRC (1998) is 4.81%. The higher essential amino acid content in the IPC fish meal did not increase performance over the Special Select™ Menhaden. This may be due to diet formulations being at or above the pigs' nutrient requirements for the feeding period.

For day 0 to 7, there were no differences ($P>0.10$) between treatments in ADG, ADFI and F/G. There was a numerical trend ($P<0.06$) for increased ADG when adding fish meal to the diet. From day 7 to 14, there was an improvement ($P<0.05$) in ADG when adding fish meal to the diet. Pigs fed diets containing fish meal had numerically higher ADFI and better feed efficiency. From day 0 to 14, ADG improved linearly ($P<0.05$) as the level of fish meal in the diet increased. There was no difference in performance between the two sources of fish meal (IPC 740 or Special Select™ Menhaden) for the duration of the trial.

In the third week (day 14 to 21) of the trial, there was no benefit in adding fish meal to the diet, as pigs on the control diet had similar ADG and better F/G ($P<0.04$) than those fed the diets containing fish meal. For the overall trial, there was no difference ($P>0.10$) in ADG, ADFI, or F/G. At the end of week 2, pigs fed the diets containing 5% fish meal had a one pound advantage in weight over the control-fed pigs, which they maintained to the end of the experiment on day 21.

The best response to adding fish meal to the diet was obtained for the first 14 days of the test. This is as expected and coincides with the time when fish meal would be used in diets in commercial production. There was no benefit to adding fish meal during the last week of the experiment. This is not surprising as the response to specialty protein sources declines with time postweaning. The response illustrates the importance of phase feeding in the nursery. Once the benefit to complex protein sources is no longer evident, they should be removed from the diet. The results of this trial agree with the work conducted by Land O'Lakes (Webster City, IA). They found no difference in performance during the first two weeks after weaning when they compared three sources of fish meal—Special Select™, IPC 790 and IPC 700 included at 6% of the diet. Based on the performance data from this study, IPC and Special Select™ can be used interchangeably in diet formulation.

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Table 2. Chemical Analysis of Two Fish Meals (As-Fed Basis)[a]

Item, %	Special Select™	IPC
Crude protein	64.25	65.2
Calcium	4.56	3.14
Phosphorus	2.82	2.11
Amino acids		
Alanine	3.81	3.82
Arginine	3.63	3.65
Aspartic acid	5.35	5.54
Cysteine	0.51	0.54
Glutamic acid	8.20	7.84
Glycine	4.51	3.92
Histidine	1.41	1.71
Hydroxylysine	0.22	0.26
Hydroxyproline	1.10	0.71
Isoleucine	2.37	2.43
Leucine	4.21	4.59
Lysine	4.48	4.95
Methionine	1.62	1.74
Ornithine	0.10	0.09
Phenylalanine	2.29	2.41
Proline	3.01	2.71
Serine	2.20	2.08
Taurine	0.49	0.51
Threonine	2.43	2.56
Tryptophan	0.66	0.74
Tryosine	1.81	1.94
Valine	2.85	2.84

[a]As fed values represent a single analysis of one batch of each fish meal.

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Table 3. Effect of Source and Level of Fish meal on Performance of Early Weaned Pigs[a]

							Probability, P<					
		IPC		Special Select™			IPC		Special Select		Control vs.	IPC vs.
Item	Control	2.5%	5%	2.5%	5%	SEM	Linear	Quadratic	Linear	Quadratic	Fish Meal	Select
D 0 to 7												
ADG, lb	0.38	0.42	0.42	0.34	0.43	0.03	0.31	0.51	0.22	0.06	0.47	0.19
ADFI, lb	0.51	0.57	0.57	0.49	0.55	0.03	0.22	0.41	0.43	0.34	0.35	0.13
F/G	1.37	1.36	1.37	1.50	1.36	0.06	0.97	0.94	0.91	0.10	0.69	0.36
D 7 to 14												
ADG, lb	0.47	0.54	0.58	0.56	0.57	0.03	0.03	0.87	0.05	0.38	0.03	0.86
ADFI, lb	0.76	0.84	0.81	0.83	0.87	0.05	0.46	0.31	0.10	0.84	0.14	0.61
F/G	1.63	1.61	1.43	1.50	1.53	0.09	0.11	0.47	0.41	0.49	0.25	0.99
D 0 to 14												
ADG, lb	0.43	0.48	0.50	0.45	0.50	0.03	0.04	0.63	0.04	0.63	0.05	0.53
ADFI, lb	0.63	0.71	0.69	0.66	0.71	0.04	0.31	0.30	0.15	0.78	0.18	0.73
F/G	1.50	1.49	1.39	1.48	1.43	0.06	0.18	0.51	0.42	0.82	0.44	0.76
D 14 to 21												
ADG, lb	1.12	1.09	1.08	1.07	1.12	0.05	0.55	0.79	0.99	0.36	0.54	0.80
ADFI, lb	1.40	1.40	1.46	1.39	1.48	0.06	0.48	0.72	0.35	0.52	0.61	0.93
F/G	1.25	1.29	1.36	1.31	1.32	0.03	0.01	0.72	0.10	0.49	0.04	0.62
D 0 to 21												
ADG, lb	0.66	0.68	0.70	0.65	0.71	0.03	0.33	0.89	0.19	0.38	0.37	0.81
ADFI, lb	0.89	0.94	0.95	0.90	0.97	0.04	0.35	0.67	0.19	0.63	0.29	0.88
F/G	1.35	1.38	1.37	1.38	1.37	0.03	0.71	0.54	0.74	0.53	0.50	0.98
Weight, lb												
D 0	14.13	14.13	14.14	14.16	14.14	0.02	0.87	0.92	0.87	0.38	0.71	0.55
D 7	16.78	17.09	17.08	16.51	17.14	0.21	0.32	0.53	0.23	0.08	0.46	0.22
D 14	20.09	20.83	21.17	20.43	21.15	0.36	0.04	0.64	0.05	0.68	0.06	0.56
D 21	27.94	28.43	28.73	27.89	29.01	0.56	0.33	0.90	0.19	0.40	0.37	0.83

[a]Means represent a total of 175 pigs, 5 pigs/pen and 7 pens/treatment.

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COMPARISON OF EDIBLE GRADE WHEY, GRANULAR WHEY, AND DAIRYLAC 80® AS LACTOSE SOURCES FOR NURSERY PIG DIETS

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

Summary

Two hundred ten weanling pigs (initially 12.4 lb and 18 ± 2 d of age) were used in a 14-d growth assay to determine the influence of various lactose sources and levels on nursery pig performance. From d 0 to 14, the mean ADG and ADFI of pigs fed additional lactose, regardless of source, was greater and tended to be greater compared to those fed no supplemental lactose. Pigs fed edible grade whey had increased ADFI and tended to have increased ADG as lactose increased from 9 to 18%. When Dairylac 80® or granular whey was included in the diet, ADG and ADFI were increased over the control, but no further improvement above the 9% level was observed. However, pigs fed 9% granular whey and Dairylac 80 had similar performance to those fed 18% edible grade whey. For pigs fed Dairylac 80, F/G also improved linearly as lactose increased to 18% in the diet. No differences in growth performance were observed among lactose sources used in this study.

(Key Words: Pig, Lactose, Whey.)

Introduction

Research with nursery pigs has demonstrated linear improvements in growth performance with increasing lactose level of the diet. The diets fed to pigs immediately after weaning routinely contain 18 to 25% lactose with edible-grade, spray-dried whey used as the standard lactose source for these diets. However, spray-dried whey is often limited in availability and more expensive than alternative lactose sources. In field experiments, Dairylac 80 and granular whey have provided similar performance when replacing edible-grade whey in the phase 2 diet. Further research is needed to determine the ability of these lactose sources to replace a high quality, edible-grade whey in the diet fed immediately after weaning.

Procedures

A total of 210 pigs (BW of 12.4 lb and 18 ± 2 d of age) were used in a 14-d growth assay. Pigs were blocked by weight and allotted to one of seven dietary treatments. The seven experimental treatments were a negative control without lactose and a 2 x 3 factorial consisting of two lactose levels (9 and 18%) and three lactose sources (edible-grade whey, Land O'Lakes; granular whey, International Ingredients Corp.; and Dairylac 80, International Ingredients Corp.). 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 waterer 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 diets were fed in pelleted form and formulated to contain 1.60% lysine (Table 1). The negative control diet contained 3% animal plasma and 2% select menhaden fish meal. Either edible-grade or granular dried whey (12.5 and 25%) replaced corn and soybean meal in the diet. Diets containing

[1]Food Animal Health and Management Center.

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Dairylac 80 were formulated to replace the lactose provided in the dried whey diets. In addition, select menhaden fish meal was used to replace the amino acids provided by dried whey. The level of fish meal increased as Dairylac 80 increased in order to keep the soybean meal levels consistent with the diets containing dried whey. Dried whey was considered to contain 72% lactose and Dairylac 80 was considered to contain 80% lactose for diet formulation.

Lactose sources and feed samples were collected for determination of percentage lactose, protein, and ash. In addition, a Pellet Durability Index was conducted on each treatment diet for determination of pellet quality. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 7 and 14 postweaning.

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

Chemical analysis of lactose sources revealed similar compositions for each product as to their labeled claims of lactose and protein percentages (Table 2). Also, ash and salt concentrations were similar for all lactose sources. In addition, the actual lactose and protein levels in each diet (Table 3) were similar to formulated values. The diets containing lactose, regardless of testing procedure, had markedly higher pellet durability indexes (PDI's) than the control diet containing no added lactose. Increases in PDI's were observed when the level of lactose was increased from 9 to 18%, regardless of source. However, diets containing either of the whey sources had superior PDI's, with diets containing Dairylac 80 having lower PDI's, regardless of procedure (Standard or Modified) used to determine PDI.

The mean of pigs fed additional lactose from d 0 to 14, regardless of source, was greater ($P<0.04$) and the mean ADFI tended to be greater ($P<0.07$) compared to pigs fed no supplemental lactose. The increased growth performance from additional lactose mainly occurred from d 0 to 7 of the experiment. Pigs fed edible grade whey had greater ADFI (linear and quadratic, $P<0$ .05) and tended to have increased ADG (linear, $P<0.06$) with increasing lactose from 9 to 18%. As whey level increased, ADG and ADFI were increased over the control diet, but no further improvement was observed in pigs fed 18% lactose. For pigs fed Dairylac 80, ADG and ADFI increased compared to those fed the no added lactose control. There were no further improvements in ADG or ADFI with increasing lactose above 9% (quadratic, $P<0.01$), but F/G improved (linear, $P<0.02$) as the level of lactose was increased from 9 to 18%. Pigs fed 9% granular whey and Dairylac 80 had similar performance to those fed 18% edible grade whey. No differences in pig growth performance were observed among sources of lactose used in this study.

It was evident by the increase in growth performance that additional lactose was beneficial to the nursery pigs in this study. Interestingly, only the edible grade whey source resulted in a linear improvement in ADG, which is commonly seen with increasing lactose in the diet. Pigs fed 9% lactose from Dairylac 80 had performance similar to pigs fed 18% lactose from edible grade whey. Increasing the lactose level to 18% did not further improve performance. This may be explained by the fact that pigs utilized in this study originated from a high health status operation and possibly may not have required as much lactose for maximal performance as is usually required under field conditions.

The slightly lower performance for pigs fed 18% lactose from Dairylac 80 compared with those fed 9% lactose from the same source may be a result of several factors. First, the decrease in performance may have been caused by a decrease in feed intake as additional fish meal was added to the diet. Fish meal was added to maintain a soybean meal level that was similar to the other lactose sources at the 18% lactose level. A second possibility may be that the slightly

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lower threonine ratio relative to lysine in this diet limited ADFI and ADG.

For the granular whey source, growth performance improved from d 0 to 7 with the response similar to the response to Dairylac 80 with no benefit to adding more than 9% lactose from granular whey. In addition, there was no benefit to including granular whey in the diet from d 7 to 14 after weaning.

Results from this experiment indicate that additional lactose is beneficial for nursery pigs with the greatest requirement during the first 7 d after weaning. Similar to other experiments, the response to adding lactose to nursery diets declined rapidly as time increased postweaning. The lactose sources used in this experiment elicited similar growth performance.

Table 1. Composition of Experimental Diets

	Control	Dried Whey		Dairylac80	
Ingredient, % Lactose, %:	0	9	18	9	18
Corn	50.23	41.09	31.93	40.73	31.15
Soybean meal (46.5% CP)	34.77	31.83	28.90	31.82	28.87
Choice white grease	5.00	5.00	5.00	5.00	5.00
Spray-dried animal plasma	3.00	3.00	3.00	3.00	3.00
Select menhaden fish meal	2.00	2.00	2.00	3.90	5.80
Dried whey[a]	-	12.50	25.00	-	-
Dairylac 80[b]	-	-	-	11.25	22.50
Monocalcium phosphate (21% P)	1.55	1.15	0.80	1.00	0.40
Limestone	0.85	0.80	0.75	0.70	0.65
Salt	0.40	0.40	0.40	0.40	0.40
Vitamin premix	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
Antibiotic[c]	1.00	1.00	1.00	1.00	1.00
Zinc oxide	0.38	0.38	0.38	0.38	0.38
Acidifier	0.20	0.20	0.20	0.20	0.20
L-lysine HCl	0.15	0.15	0.15	0.15	0.15
DL-methionine	0.08	0.10	0.10	0.08	0.10
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis:					
Lysine, %	1.60	1.60	1.60	1.60	1.60
Methionine:lysine, %	28	29	28	28	30
Met & Cys:lysine, %	56	56	55	55	55
Threonine:lysine, %	61	62	63	60	59
Tryptophan:lysine, %	19	19	19	20	20
Isoleucine:lysine, %	62	62	62	61	60
Protein, %	24.0	23.4	22.8	23.6	23.2
ME, kcal/lb	1,576	1,570	1,564	1,593	1,609
Calcium, %	0.85	0.84	0.84	0.84	0.85
Phosphorus, %	0.82	0.78	0.75	0.78	0.74
Available phosphorus, %	0.50	0.50	0.51	0.51	0.50
Lysine:calorie ratio, g/Mcal	4.61	4.62	4.64	4.56	4.51

[a]Edible-grade (Land O'Lakes, Arden Hills, MN) or granular dried whey (International Ingredients Corp., St. Louis, MO).
[b]International Ingredients Corp., St Louis, MO.
[c]Provided 50 g per ton carbadox.

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Table 2. Chemical Composition of Experimental Lactose Sources

Chemical Analysis, %	Edible Grade Whey[a]	Granular Whey[b]	Dairylac 80[b]
Lactose	72.8	72.1	80.2
Protein	11.5	12.3	5.01
Ash	7.99	7.93	8.02
Salt	3.07	2.80	2.98

[a]Land O'Lakes, Arden Hills, MN.
[b]International Ingredients Corp., St Louis, MO.

Table 3. Chemical Composition and Physical Characteristics of Experimental Diets

	Control	Edible Grade Whey[a]		Granular Whey[b]		Dairylac 80[b]	
Analysis Lactose, %:	0	9	18	9	18	9	18
Protein, %	24.9	23.8	23.2	24.0	23.5	23.3	23.8
Ash, %	6.86	6.81	7.53	6.93	7.20	7.37	7.61
Lactose, %	1.21	9.17	16.7	10.5	17.2	10.5	17.6
Pellet durability index, %							
Standard[c]	87.6	95.7	97.5	94.0	96.6	89.0	94.2
Modified[d]	71.6	89.3	95.0	87.6	93.3	80.0	87.4

[a]Land O'Lakes, Arden Hills, MN.
[b]International Ingredients Corp., St Louis, MO
[c]Am. Soc. Agric. Engin. Procedure.
[d]Am. Soc. Agric. Engin. Procedure modified with the addition of five ½-inch hexagonal nuts prior to tumbling.

Table 4. Effect of Lactose Source and Level on Nursery Pig Growth Performance[a]

	Control	Edible Grade Whey[b]		Granular Whey[c]		Dairylac 80[c]		
Item Lactose, %:	0	9	18	9	18	9	18	SEM
Day 0 to 7								
ADG, lb	0.37	0.40	0.48	0.51	0.49	0.52	0.45	0.04
ADFI, lb	0.35	0.37	0.45	0.43	0.45	0.45	0.39	0.03
F/G	0.95	0.93	0.94	0.84	0.92	0.87	0.87	0.05
Day 7 to 14								
ADG, lb	0.68	0.67	0.77	0.65	0.65	0.77	0.72	0.04
ADFI, lb	0.74	0.70	0.85	0.72	0.74	0.85	0.74	0.04
F/G	1.09	1.04	1.10	1.11	1.14	1.10	1.03	0.04
Day 0 to 14								
ADG, lb	0.52	0.53	0.62	0.58	0.56	0.64	0.58	0.03
ADFI, lb	0.55	0.53	0.65	0.58	0.60	0.65	0.56	0.02
F/G	1.06	1.00	1.05	1.00	1.07	1.02	0.97	0.04

[a]A total of 210 pigs (5 per pen and 6 pens per treatment) with an initial BW of 12.4 lbs.
[b]Edible grade whey was from Land O'Lakes, Arden Hills, MN.
[c]Granular whey and Dairylac 80 were from International Ingredients Corp., St Louis, MO.

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Table 5. Probability of Lactose Source and Level on Nursery Pig Growth Performance[a]

					Edible		Granular		Dairylac	
Item	Control vs. Others	Edible[b] vs. Granular[c]	Edible vs. Dairylac[c]	Granular vs. Dairylac	Lin	Quad	Lin	Quad	Lin	Quad
Day 0 to 7										
ADG, lb	0.02	0.11	0.23	0.66	0.09	0.64	0.02	0.07	0.12	0.03
ADFI, lb	0.02	0.23	0.68	0.42	0.03	0.30	0.01	0.38	0.33	0.03
F/G	0.25	0.21	0.13	0.77	0.81	0.99	0.39	0.02	0.10	0.57
Day 7 to 14										
ADG, lb	0.61	0.11	0.61	0.04	0.18	0.34	0.65	0.86	0.51	0.16
ADFI, lb	0.47	0.25	0.52	0.08	0.09	0.09	0.99	0.78	0.98	0.01
F/G	0.99	0.09	0.78	0.15	0.99	0.32	0.49	0.84	0.22	0.18
Day 0 to 14										
ADG, lb	0.04	0.86	0.24	0.18	0.06	0.36	0.27	0.33	0.11	0.01
ADFI, lb	0.07	0.84	0.50	0.38	0.01	0.05	0.23	0.88	0.63	0.01
F/G	0.23	0.90	0.28	0.23	0.88	0.37	0.94	0.08	0.02	0.66

[a]A total of 210 pigs (five per pen and six pens per treatment) with an initial BW of 12.4 lb.
[b]Edible grade whey was from Land O'Lakes, Arden Hills, MN.
[c]Granular whey and Dairylac 80 were from International Ingredients Corp., St Louis, MO.

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EVALUATION OF GROUND CORN GERM AS AN ENERGY SOURCE IN NURSERY DIETS [1]

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

Summary

Two hundred eighty nursery pigs (initially 30.9 lb) were used in a 21-d growth assay to determine the energy value of ground corn germ relative to corn oil in nursery diets. Increasing dietary corn oil linearly decreased average daily feed intake and improved feed efficiency. However, pigs fed diets containing ground corn germ meal had similar gain and feed efficiency as those fed the corn-soybean meal diet without added fat. These results suggest that the added energy provided by corn germ is not utilized as well as that from corn oil.

(Key Words; Nursery Pigs, Corn Germ, Energy Source, Fat.)

Introduction

Corn germ is a by-product of the corn milling industry. It has a high fat content (45 to 50%) and can be handled as a free flowing product. Thus, corn germ may provide an opportunity for swine producers to increase energy density of diets. The greatest application may be in two specific areas. First, producers who cannot handle liquid fat sources easily in their on-farm feed mill may want to use corn germ to increase energy density. Second, some producers that are already using high fat diets would like to further increase the energy density, but cannot because of problems with flowability of the feed. Thus, corn germ may provide an opportunity to further increase energy density of the diet. Currently we are unaware of any data validating the use of corn germ as an energy source in swine diets. Therefore, our objective was to determine the energy value of corn germ relative to corn oil in diets for nursery pigs.

Procedures

Two hundred eighty nursery pigs (initially of 30.9 lb) were used in a 21-d growth assay. Pigs were blocked by weight and allotted to one of seven treatments. There were five pigs/pen and eight pens per 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.

Experimental diets included a corn-soybean meal control diet with no added fat. Additional diets included increasing amounts of oil (2, 4, and 6%) provided by either corn oil or corn germ. The composition of corn germ is shown in Table 1. All diets were formulated to the same lysine/calorie ratio of 3.82 g lysine/ Mcal of ME (Table 2). In diet formulation, corn germ was assumed to contain 50% of its weight as fat for an energy source. Average daily gain, average daily feed intake, and feed efficiency were determined by weighing pigs and measuring feed disappearance on d 7, 14, and 21 of the experiment.

[1]We would like to acknowledge Minnesota Corn Processors for providing the corn germ meal and partial financial support for this research project.

[2]Food Animal Health and Management Center.

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Table 1. Nutrient Profile of Corn Germ[a]

Metabolizable energy, Kcal/lb	2,375
Nutrient composition, %	
Dry matter	95.44
Crude protein	14.17
Crude fat	45.03
Acid detergent fiber	10.31
Neutral detergent fiber	22.18
Ash	.85
Phosphorus	.37
Calcium	.02
Amino Acid Composition, %	
Tryptophan	0.11
Cystine	0.21
Methionine	0.26
Threonine	0.45
Serine	0.54
Glycine	0.59
Alanine	0.72
Isoleucine	0.69
Leucine	0.43
Tryosine	1.02
Phenylalanine	0.42
Lysine (Total)	0.54
Histidine	0.53
Arginine	0.37

[a]Nutrient values were provided by the supplier.
[b]A calculated energy value derived from an NRC (1998) equation estimating the kcal ME based on the nutrient composition of the feed ingredient.

Data was analyzed as a randomized complete block design with a pen as the experimental unit. Linear and quadratic polynomial contrasts were used to determine the effects of increasing levels of fat and fat source.

Results and Discussion

For the overall 21-d study, pigs fed diets containing corn oil had improved ($P<0.04$) ADG, ADFI, and F/G compared to those fed diets containing ground corn germ (Table 3 and 4). For the overall period, a fat source by level interaction was observed for F/G. The interaction was because F/G improved linearly when increasing levels of corn oil were added to the diet, whereas increasing fat from ground corn germ had no effect on performance. Pigs fed diets containing corn oil had decreased ADFI (linear, $P<0.005$) and improved feed efficiency (linear, $P<0.001$). However, increasing corn oil had no effect ($P>0.10$) on overall ADG. Overall pigs fed diets containing ground corn germ meal were similar in growth performance to those fed the control diet with no added fat. The response to corn oil is consistent with other research indicating that increasing the energy density of the diet decreases average daily feed intake and improves feed efficiency.

These findings suggest that the energy in ground corn germ meal is not as available as the energy in corn oil for nursery pigs. Ground corn germ contains a high amount of fiber (23.85%ADF and 43.36% NDF), which could explain the poorer performance. Although corn germ would be expected to have a high energy value because of its fat content, it appears that it is offset by its high fiber content. In conclusion, these data suggest that corn germ, despite containing 45 to 50% fat, does not improve feed efficiency compared with the same amount of added fat from corn oil.

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Table 2. Diet Composition (As Fed Basis)

		Corn Oil			Ground Corn Germ		
Ingredient	Control	2%	4%	6%	2%	4%	6%
Corn	62.80	59.15	55.66	52.05	57.74	57.80	47.80
Soybean meal (46.5%)	33.38	35.02	36.51	38.11	34.44	35.35	36.37
Soybean oil		2	4	6			
Corn germ meal					4	8	12
Monocalcium phosphate (21% P)	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Limestone	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Antibiotic[a]	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Lysine HCl	0.10	0.10	0.10	0.10	0.10	0.10	0.10
DL-methionine	0.015	0.015	0.015	0.015	0.015	0.015	0.015
TOTAL	100	100	100	100	100	100	100
Calculated Analysis							
Lysine, %	1.250	1.290	1.326	1.365	1.290	1.326	1.365
Isoleucine:lysine ratio, %	69	69	69	69	69	69	69
Leucine:lysine ratio, %	147	145	142	140	145	143	141
Methionine:lysine ratio, %	28	28	27	28	27	27	28
Met & Cys:lysine ratio, %	57	57	56	56	56	56	56
Threonine:lysine ratio, %	64	64	63	63	64	64	63
Tryptophan:lysine ratio, %	20	20	20	20	20	20	20
Fat, %	3.5	5.4	7.3	9.2	5.3	7.1	9.0
Protein, %	20.9	21.3	21.7	22.1	21.5	22.0	22.6
Available phosphorus, %	0.39	0.39	0.39	0.40	0.39	0.40	0.40
Lysine:calorie ratio, g/mcal	3.82	3.82	3.82	3.82	3.82	3.82	3.83

[a]Provided 50 g/ton carbadox.

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Table 3. Effects of Fat Source from Corn Oil or Ground Corn Germ on Nursery Pigs[a]

		Corn Oil			Ground Corn Germ			
Item Fat Level	0 %	2 %	4%	6%	2 %	4%	6%	SEM
D 0 to 7								
ADG, lb	1.47	1.43	1.41	1.42	1.33	1.37	1.41	0.047
ADFI, lb	1.94	2.00	1.90	1.83	1.95	1.88	1.95	0.043
F/G	1.33	1.41	1.36	1.29	1.48	1.37	1.39	0.029
D 7 to 14								
ADG, lb	1.69	1.69	1.71	1.70	1.64	1.62	1.72	0.048
ADFI, lb	2.55	2.58	2.44	2.42	2.52	2.49	2.54	0.042
F/G	1.52	1.53	1.43	1.42	1.53	1.54	1.47	0.039
D 14 to 21								
ADG, lb	1.76	1.90	1.89	1.94	1.95	1.86	1.84	0.069
ADFI, lb	2.95	2.95	2.95	2.87	3.04	3.07	3.00	0.054
F/G	1.77	1.57	1.56	1.48	1.56	1.65	1.64	0.073
D 0 to 21								
ADG, lb	1.64	1.67	1.67	1.69	1.64	1.62	1.66	0.026
ADFI, lb	2.48	2.51	2.43	2.38	2.50	2.48	2.50	0.032
F/G	1.52	1.50	1.46	1.41	1.52	1.53	1.51	0.017

[a]A total of 280 pigs (five pigs per pen and eight pens per treatment) with an average initial BW of 30.9 lb.

Table 4. Probability Of Effects Of Fat Source From Corn Oil Or Ground Corn Germ On Nursery Pigs[a]

	P- Value			Corn oil		Ground Corn Germ	
Item	Fat level	Fat source	Level*Source	Linear	Quadratic	Linear	Quadratic
D 0 to 7							
ADG, lb	0.72	0.23	0.67	0.54	0.63	0.53	0.05
ADFI, lb	0.09	0.59	0.13	0.06	0.21	0.86	0.47
F/G	0.005	0.03	0.45	0.28	0.02	0.48	0.01
D 7 to 14							
ADG, lb	0.44	0.22	0.36	0.81	0.90	0.77	0.17
ADFI, lb	0.04	0.23	0.06	0.008	0.56	0.77	0.46
F/G	0.02	0.02	0.15	0.07	0.90	0.47	0.39
D 14 to 21							
ADG, lb	0.59	0.54	0.34	0.12	0.51	0.70	0.20
ADFI, lb	0.29	0.008	0.88	0.37	0.50	0.47	0.18
F/G	0.44	0.02	0.11	0.03	0.50	0.50	0.31
D 0 to 21							
ADG, lb	0.39	0.03	0.78	0.22	0.72	0.82	0.60
ADFI, lb	0.07	0.04	0.13	0.005	0.15	0.87	0.95
F/G	0.002	<0.001	0.03	<0.001	0.39	0.77	0.42

[a]A total of 280 pigs (five pigs per pen and eight pens per treatment) with an average initial BW of 30.9 lb.

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COMPARISON OF YELLOW DENT AND NUTRIDENSE CORN HYBRIDS FOR NURSERY PIG DIETS [1]

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

Summary

A total of 315 nursery pigs (initially 33.5 lb) were used in a 21-d growth assay to compare relative energy values of 'Nutridense' and 'Nutridense Low Phytate' corn compared to Yellow Dent corn. Dietary treatments consisted of a 3 × 3 factorial with three sources of corn with 0, 3, or 6% added fat. Increasing the energy density of the diet with added fat or higher energy corn varieties (Nutridense or Nutridense-LP corn) linearly improved feed efficiency. The linear improvement in feed efficiency allowed us to calculate the energy content of the Nutridense corn varieties relative to Yellow Dent corn. We determined that the ME values published by the University of Illinois indicating that Nutridense and Nutridense Low Phytate corn contain approximately 6.5 and 4% more energy, respectively, than normal Yellow Dent corn are appropriate for diet formulation.

Key Words; Corn, Fat, Energy, Nursery Pigs.)

Introduction

Nutridense corn is a nutritionally enhanced product containing traits to provide greater nutrient density than conventional yellow Dent corn. Specifically, it contains approximately 30% more lysine, 50% more sulfur amino acids, 18% more threonine, almost 100% more tryptophan and 6% more energy than normal corn. Exseed Genetics, LLC also produces a low phytate Nutridense corn (Nutridense-LP) that contains approximately 75% available P compared to about 14% available P for normal corn.

Experiments have been conducted at the University of Illinois to determine the available P content of Nutridense and Nutridense-LP corn and the energy value of these hybrids compared to normal corn. These experiments confirmed the predicted value of most nutrients with the exception of the energy value for the low phytate corn. Nutridense and Nutridense-LP were expected to contain approximately 6 and 9% more energy than normal yellow corn, respectively. The experimental results indicated the advantages were approximately 6.5 and 4%, respectively.

Therefore, this experiment was designed to determine the relative energy density of Nutridense and Nutridense-LP in diets for pigs in the late nursery stage. A second objective was to determine whether higher energy density diets could be achieved using Nutridense corn in conjunction with high levels of added dietary fat.

Procedures

A total of 315 pigs (33.5 lb) were used in a 21-day growth assay. Pigs were blocked by weight and allotted to one of nine treatments. There were five pigs per pen and seven pens per 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

[1]Appreciation is expressed to Exseed Genetics LLC, for partial financial support for this trial.
[2]Food Animal Health and Management Center.

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to provide ad libitum access to feed and water.

The nine diets for the experiment included three corn sources (Yellow Dent corn, Nutridense corn, and Nutridense Low Phytate corn) each with increasing levels of added fat (0, 3, and 6 %). Nutrient values for Nutridense and Nutridense Low Phytate corn were provided by Exseed (Table 1). The energy value for Nutridense and Nutridense-LP corn was calculated at 6 and 9% greater than the value of Yellow Dent corn in diet formulation. Nutrient values for Yellow Dent corn were from N□C (1998). All experimental diets where balanced to maintain a constant lysine to calorie ratio and available phosphorus level (Table 2).

Pigs were weighed and feed disappearance was measured every 7 days to determine ADG, ADFI, and feed efficiency. Data were analy□ed as a randomi□ed complete block design with pen as the experimental unit. After testing for interactions between corn source and fat level, linear and □uadratic polynomial contrasts were used to determine the effects of increasing levels of fat. Single degree of freedom contrasts were used to determine differences among corn sources.

Results and Discussion

□esults from this trial are listed in Tables 3, 4, and 5 with interactive means shown in Table 3, main effects of corn source and fat levels in Table 4, and probabilities of differences in Table 5. There was no corn source by fat level interaction except for ADG from d 14 to 21. This interaction occurred because ADG increased when fat was increased from 0 to 3% for pigs fed Nutridense or Yellow Dent corn; however, ADG decreased as the fat level increased from 0 to 3% for pigs fed Nutridense-LP corn. This interaction did not influence the overall response to corn source or fat level.

There was no difference in ADG, ADFI or F/G among corn sources from d 0 to 7. Increasing the fat level from 0 to 6% decreased (linear, $P<0.01$) ADFI and improved (linear, $P<0.01$; □uadratic, $P<0.03$) F/G. A similar response to increasing fat levels was found for d 7 to 14 and d 14 to 21 with ADFI being reduced and F/G being improved linearly ($P<0.01$). From d 7 to 14, ADFI was lower ($P<0.01$) and F/G was improved ($P<0.02$) for pigs fed Nutridense and Nutridense-LP corn compared with pigs fed Yellow Dent corn. From d 14 to 21, pigs fed Nutridense and Nutridense-LP corn had lower ($P<0.01$) ADFI than pigs fed Yellow Dent corn; however, the only difference in feed efficiency was the improvement ($P<0.03$) for pigs fed Nutridense corn compared to Yellow Dent corn.

Overall, there was no difference ($P>0.11$) among corn sources for ADG. However, ADFI was decreased ($P<0.02$) and F/G was improved ($P<0.05$) for pigs fed Nutridense or Nutridense-LP corn when compared to pigs fed Yellow Dent corn. There were no differences in pig performance when comparing Nutridense and Nutridense-LP corn for any of the response criteria. Increasing fat levels linearly reduced ($P<0.01$) ADFI and improved ($P<0.001$) F/G in every period and for the overall trial.

Analysis of our data indicates that ME was approximately 5 and 3% higher for the two respective Nutridense corn varieties than for Yellow Dent corn. Our results agree with the work from the University of Illinois indicating that Nutridense and Nutridense-LP corn have higher ME content than Yellow Dent corn. Their research determined that ME was increased by 6.5 and 4% for Nutridense and Nutridense-LP corn, respectively, compared with Yellow Dent corn. The small differences between our results and theirs may be because the Yellow Dent corn used in our experiment was higher in energy and, thus, a relatively smaller difference was calculated. Additionally, we used the N□C (1998) value for Yellow Dent corn rather than the analy□ed value used by the University of Illinois. Also, if the energy values from the University of Illinois are used to calculate dietary energy content in a regression e□uation with the actual feed efficiency values of each individual pen, the resultant linear fit is □uite good (r^2 □0.55; $P<0.01$; Figure 1). If the treatment means are used for the regression e□uation instead of

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the pen means, the quality of the fit is even better (Figure 2). Our results indicate that the higher ME values determined by the University of Illinois for Nutridense and Nutridense-LP corn compared with Yellow Dent corn are appropriate for diet formulation.

A second goal of our study was to evaluate the ability to achieve higher energy diets with Nutridense corn compared with Yellow Dent corn and added fat. We were able to demonstrate linear improvements in feed efficiency through the highest levels of added fat with all corn varieties. This indicates that higher dietary energy density and further improvements in feed efficiency can be achieved with Nutridense corn and added fat compared with Yellow Dent corn and added fat. A corn soybean meal-based diet with 6% added fat is the maximum limit of added fat to prevent feed handling problems. Thus, the Nutridense corn may provide an option to feed an even higher energy density diet.

Table 1. Composition of Corn Sources

Item	Yellow Dent Corn	Nutridense	Nutridense LP
Dry Matter, %	89	88	88
Oil, %	3.9	4.8	4.8
Protein, %	8.3	10	10
ME, kcal/lb	3420	3625[a]	3728[a]
Fiber, %	2.8	2	2
Calcium, %	0.03	0.01	0.01
Phosphorus (Total), %	0.28	0.32	0.32
Phosphorus (Available), %	14	0.11	0.3
Magnesium, %	0.12	0.13	0.13
Potassium, %	0.33	0.35	0.35
Sulfur, %	0.13	0.11	0.11
Amino acids, %			
Lysine	0.26	0.31	0.31
Arginine	0.37	0.52	0.52
Cystine	0.19	0.23	0.25
Isoleucine	0.28	0.41	0.41
Leucine	0.99	1.35	1.35
Methionine	0.17	0.21	0.24
Tryptophan	0.06	0.07	0.07
Threonine	0.29	0.34	0.38
Valine	0.39	0.55	0.56

[a]Metabolizable energy value for corn was estimated at 6 and 9% greater than the ME of Yellow Dent corn for Nutridense and Nutridense-LP corn, respectively.

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Table 2. Composition of Experimental Diets (As-Fed-Basis)

Corn source:	Yellow Dent			Nutridense			Nutridense LP		
Ingredient, lb/ton Fat, %:	0	3	6	0	3	6	0	3	6
Corn source	62.79	57.61	52.46	62.17	57.04	52.02	61.64	56.57	51.55
Soybean meal (46.5%)	33.38	35.55	37.68	34.13	36.24	38.25	35.11	37.12	39.13
Choice white grease	0	3.00	6.00	0	3.00	6.00	0	3.00	6.00
Monocalcium phosphate (21% P)	1.50	1.50	1.50	1.30	1.30	1.30	0.90	0.95	0.95
Limestone	0.95	0.95	0.95	1.05	1.05	1.05	1.00	1.00	1.00
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Antibiotic	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Lysine HCl	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
DL-methionine	0.03	0.04	0.06	0	0.02	0.03	0	0.02	0.03
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Calculated Analysis:									
Lysine, %	1.25	1.30	1.35	1.30	1.35	1.40	1.33	1.38	1.42
Isoleucine:lysine ratio, %	69	69	69	76	75	75	76	75	74
Leucine:lysine ratio, %	147	144	140	156	151	147	155	150	146
Methionine:lysine ratio, %	28	29	30	28	28	28	29	29	29
Met & Cys:lysine ratio, %	58	57	58	59	58	58	60	59	59
Threonine:lysine ratio, %	64	63	63	65	64	63	66	66	65
Tryptophan:lysine ratio, %	20	20	20	20	20	20	20	20	20
Valine:lysine ratio, %	80	79	78	86	84	83	86	84	83
ME, kcal/lb	1,486	1,547	1,608	1,546	1,602	1,658	1,581	1,634	1,688
Protein, %	20.9	21.4	22.0	22.1	22.6	23.0	22.5	22.9	23.3
Calcium, %	0.77	0.78	0.78	0.76	0.77	0.77	0.67	0.69	0.69
Phosphorus, %	0.72	0.72	0.72	0.71	0.71	0.70	0.63	0.64	0.63
Available phosphorus, %	0.39	0.39	0.40	0.39	0.39	0.39	0.39	0.39	0.39
Lysine:calorie ratio, g/mcal	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82

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

Corn source:	Yellow Dent			Nutridense			Nutridense LP		
Item Fat, %:	0	3	6	0	3	6	0	3	6
D 0 to 7									
ADG, lb	1.35	1.31	1.35	1.27	1.29	1.31	1.34	1.32	1.35
ADFI, lb	2.07	1.99	1.89	1.96	1.98	1.83	2.05	2.01	1.93
F/G	1.54	1.54	1.41	1.54	1.54	1.40	1.53	1.53	1.43
D 7 to 14									
ADG, lb	1.69	1.73	1.74	1.61	1.73	1.71	1.68	1.73	1.67
ADFI, lb	2.81	2.64	2.63	2.63	2.53	2.48	2.60	2.58	2.46
F/G	1.67	1.53	1.52	1.63	1.46	1.45	1.55	1.49	1.48
D 14 to 21									
ADG, lb	1.79	1.99	1.94	1.85	1.92	1.87	1.86	1.80	1.89
ADFI, lb	3.05	3.13	2.96	2.93	2.90	2.84	3.07	2.86	2.79
F/G	1.70	1.57	1.53	1.59	1.52	1.52	1.65	1.60	1.48
Overall									
ADG, lb	1.61	1.67	1.67	1.57	1.65	1.63	1.63	1.62	1.64
ADFI, lb	2.64	2.58	2.49	2.50	2.47	2.38	2.57	2.48	2.40
F/G	1.64	1.54	1.49	1.59	1.50	1.46	1.58	1.54	1.46

[a]A total of 315 pigs (five pigs per pen and seven pens per treatment) with an average initial BW of 33.5 lb.

Table 4. Main Effects of Corn Source and Level of Fat on Growth Performance of Phase III Nursery Pigs[a]

	Corn Source			Fat Level		
Item	Yellow Dent	Nutridense	Nutridense LP	0%	3%	6%
D 0 to 7						
ADG, lb	1.34	1.29	1.34	1.32	1.31	1.34
ADFI, lb	1.98	1.92	2.00	2.03	1.99	1.89
F/G	1.50	1.49	1.50	1.53	1.54	1.42
D 7 to 14						
ADG, lb	1.72	1.69	1.69	1.66	1.73	1.71
ADFI, lb	2.69	2.55	2.54	2.68	2.59	2.52
F/G	1.57	1.52	1.51	1.62	1.49	1.48
D 14 to 21						
ADG, lb	1.91	1.88	1.85	1.83	1.91	1.90
ADFI, lb	3.04	2.89	2.91	3.02	2.96	2.86
F/G	1.61	1.54	1.58	1.65	1.56	1.50
Overall						
ADG, lb	1.65	1.62	1.63	1.60	1.65	1.65
ADFI, lb	2.57	2.45	2.48	2.57	2.51	2.42
F/G	1.56	1.52	1.53	1.60	1.53	1.47

[a]A total of 315 pigs (five pigs per pen and 21 pens per treatment) with an average initial BW of 33.5.

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Table 5. Probability of Source and Level of Corn Source and Fat on Growth Performance of Phase III Nursery Pigs[a]

				Corn Source			Fat Level		
Item	Level	Source	Source × Level	Yellow vs. Nutridense	Yellow vs. Nurtidense LP	Nutridense vs. Nutridense LP	Linear	Quad	SE
D 0 to 7									
ADG, lb	0.77	0.51	0.99	0.31	0.99	0.31	0.72	0.54	0.05
ADFI, lb	0.02	0.33	0.92	0.27	0.75	0.16	0.008	0.41	0.06
F/G	0.001	0.95	0.98	0.80	0.99	0.78	0.001	0.03	0.04
D 7 to 14									
ADG, lb	0.15	0.65	0.73	0.38	0.49	0.86	0.19	0.15	0.04
ADFI, lb	0.01	0.007	0.83	0.01	0.01	0.98	0.003	0.70	0.06
F/G	0.001	0.02	0.33	0.02	0.01	0.78	0.001	0.01	0.03
D 14 to 21									
ADG, lb	0.08	0.25	0.04	0.42	0.10	0.39	0.06	0.21	0.04
ADFI, lb	0.01	0.007	0.20	0.004	0.01	0.76	0.004	0.56	0.06
F/G	0.001	0.08	0.25	0.03	0.32	0.20	0.001	0.51	0.03
Overall									
ADG, lb	0.07	0.24	0.55	0.11	0.22	0.69	0.04	0.28	0.03
ADFI, lb	0.001	0.006	0.97	0.002	0.02	0.39	0.001	0.67	0.04
F/G	0.001	0.02	0.53	0.01	0.05	0.43	0.001	0.39	0.02

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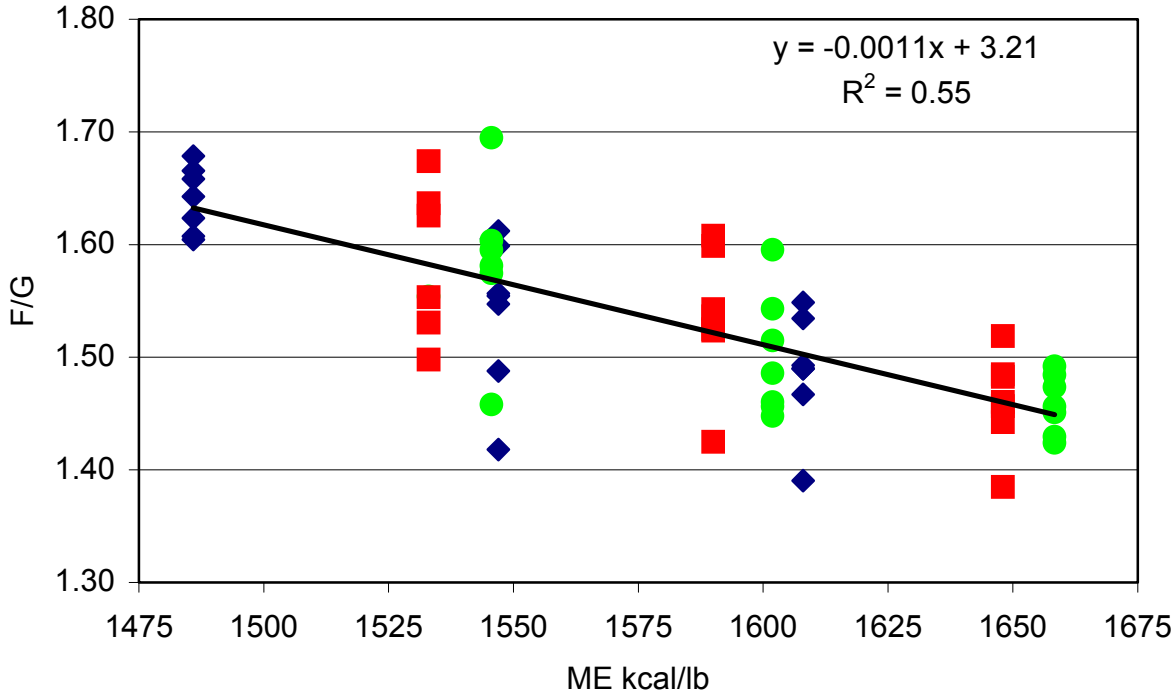

Figure 1. Relationship between dietary energy density for the nine dietary treatments and feed efficiency for the individual pens (♦ Yellow Dent corn; ■ Nutridense-LP corn; and ● Nutridense corn.

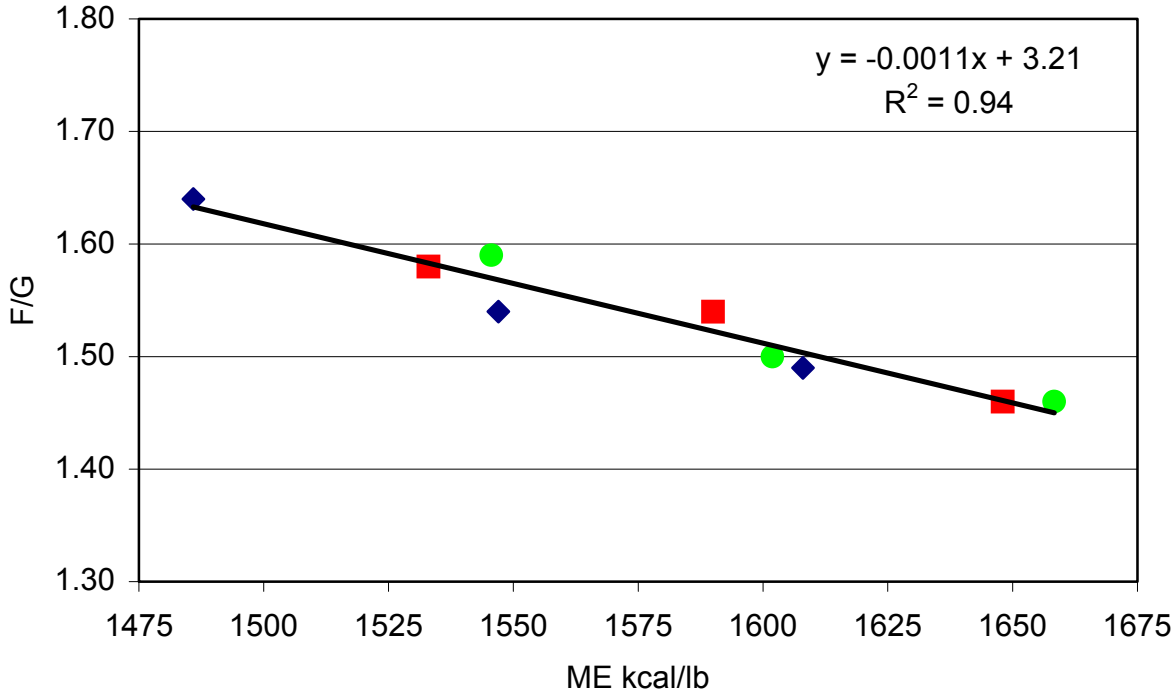

Figure 1. Relationship between dietary energy density for the nine dietary treatments and the treatment means for feed efficiency (♦ Yellow Dent corn; ■ Nutridense-LP corn; and ● Nutridense corn.

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EFFECTS OF SOYBEAN MEAL PARTICLE SIZE ON GROWTH PERFORMANCE OF NURSERY PIGS [1]

K. R. Lawrence, C. W. Hastad, R. D. Goodband, M. D. Tokach, J. L. Nelssen, S. S. Dritz [2], and M. J. Webster

Summary

A total of 360 pigs were used in two experiments to determine the effects of decreasing particle size of soybean meal on nursery pig performance. In Exp. 1, pigs were fed diets containing 34% extruded-expelled soybean meal ground to 965, 742, or 639 microns. In Exp. 2, pigs were fed the same diet containing solvent extracted soybean meal ground to 1226, 797, or 444 microns. Decreasing soybean meal particle size did not influence pig growth performance in either study.

(Key Words: Pigs, Soybean Meal, Particle Size.)

Introduction

Reducing particle size of grain in swine diets increases surface area allowing for greater interaction with digestive enzymes and improved digestibility. We recommend a particle size of 600 to 700 microns for grain in diets to optimize growth performance and improve feed efficiency. While it has been confirmed that fine grinding of grain in swine diets optimizes performance, there is limited information on the effects of soybean meal particle size on pig performance.

Researchers at The Ohio State University observed that decreasing soybean meal particle size resulted in improved amino acid digestibility in growing-finishing diets. Therefore, our objective was to evaluate the influence of reducing particle size of extruded-expelled soybean meal and solvent extracted soybean meal on growth performance of nursery pigs.

Procedures

A total of 360 pigs (initially 20.9 lb and 35 ± 3 d of age) were used in two 21−d growth assays. There were six pigs/pen and 10 pens per treatment. Pigs were fed the same SEW diet for 7 d after weaning, followed by a common Phase 2 diet from d 7 to 14. On d 14, all pigs were weighed and blocked by weight and allotted to one of three dietary treatments. All diets were corn-soybean meal-based and formulated to 1.2% lysine, 0.78% calcium, and 0.40% available phosphorus (Table 1). In Exp. 1, we used a single lot of extruded-expelled soybean meal ground to achieve particle sizes of 965, 742, or 639 microns, which resulted in whole diet particle sizes of 728, 719, and 697 microns. In Exp. 2, we used one lot of solvent extracted soybean meal ground to achieve particle sizes of 1,226, 797, and 444 microns, which resulted in whole diet particle sizes of 732, 681, and 629, respectively.

All pigs were housed in the KSU Swine Teaching and Research Center's environmentally controlled nursery, with a self-feeder and nipple waterer in each pen to allow ad libitum access to feed and water.

[1]Appreciation is expressed to North Central Kansas Processors, Washington, KS, and Cargill, Inc., Kansas City, KS, for providing the extruded-expelled soybean meal and the solvent extracted soybean meal, respectively.

[2]Food Animal Health and Management Center.

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Average daily gain, average daily feed intake, and feed efficiency were determined by weighing pigs and measuring feed disappearance on d 7, 14, and 21 of the experiment.

Table 1. Experimental Diets (fed from d 14 to 35 after weaning)[a]

Ingredient, %	
Corn	61.90
Soybean meal[b]	34.41
Monocalcium phosphate (21% P)	1.50
Limestone	0.95
Salt	0.35
Vitamin premix	0.25
Trace mineral premix	0.15
Mecadox[c]	0.50
Total	100.00
Calculated analysis, %	
Lysine	1.20
Isoleucine:lysine ratio	74
Met & Cys:lysine ratio	59
Threonine:lysine ratio	68
Tryptophan:lysine ratio	22
Valine:lysine ratio	85
Protein	21.3
Calcium	.77
Phosphorus	.73
Available phosphorus	.39

[a]Values calculated on an as-fed basis.
[b]Diets in Exp.1 contained extruded-expelled soybean meal (46.0% CP) and Exp. 2 contained solvent extracted soybean meal (46.5% CP).
[c]Provided 25g/ton carbadox.

Physical properties of ingredients can affect their flowability in holding bins and feeders. Particle size is correlated with flowability; as particle size increases flowability improves, and as particle size decreases flowability becomes poorer. The flowability of a diet is measured by angle of repose. Angle of repose is defined as the maximum angle (degrees) at which a pile of material retains its slope. Thus, a product with a high angle of repose would be expected to flow poorly, and a product with low angle of repose would flow more freely. In order to determine if particle size would affect flowability, we measured angle of repose on both soybean meal and complete diets.

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 soybean meal particle size. Both experiments had matching design with the exception that Exp.1 used extruded-expelled soybean meal and Exp. 2 used solvent extracted soybean meal

Results and Discussion

In Exp. 1, reducing particle size of extruded-expelled soybean meal (965 to 639 microns) increased the angle of repose. However, the angle of repose of the complete diets was greater than for the soybean meals. This would indicate that reducing particle size of soybean meal does not have a major impact on its flow characteristics relative to the complete diet. In addition, the differences in extruded-expelled soybean meal particle size resulted in approximately a 30-micron difference in the complete diet. Therefore, we would not expect a large difference in feed efficiency and no differences ($P>0.10$) in pig performance were found.

In Exp. 2, reducing particle size of solvent extracted soybean meal (1,226 to 444 microns) increased the angle of repose as in Exp. 1. The angle of repose of the complete diets in Exp. 2 was also greater than for the soybean meal diets, which indicates that the 444 micron soybean meal used in our study actually had a lower angle of repose (greater flowability) than the complete diet with a particle size of 629 microns. The change in soybean meal particle size from 1,226 to 444 microns resulted in a change in overall diet particle size of approximately 100 microns. However, like in Exp. 1, decreasing soybean meal particle size had no affect on pig performance.

Previous research from The Ohio State University has shown that apparent digest-

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ibility of amino acids increased as soybean meal particle size decreased. While decreasing soybean meal particle size may improve amino acid digestibility, we did not observe differences in growth performance. If our diets were formulated above the pig's lysine requirement, the changes in amino acid digestibility may not result in improved pig performance. We also might expect the digestible energy content of the diet to increase slightly with finely ground soybean meal, but again, because of the relatively low inclusion of soybean meal in the diets relative to grain, we were not able to detect any differences in pig performance.

In conclusion, while it is extremely important to finely grind the grain portion of swine diets to a particle size of 600 to 700 microns, based on the results of these two studies, soybean meal particle size does not appear to affect pig growth performance.

Table 2. Effects of Extruded-Expelled Soybean Meal Particle Size on Growth Performance (Exp. 1)

	Soybean Meal Particle Size, Microns				P Values		
Item	639	742	965	SEM	Treatment	Linear	Quadratic
Angle of repose[b]							
Soybean meal	51.9	48.00	44.19	—	—	—	—
Diet	55.64	55.07	52.38	—	—	—	—
Diet particle size	697	719	728	—	—	—	—
Day 0 to 21							
ADG, lb	1.19	1.18	1.19	0.27	0.97	0.97	0.82
ADFI, lb	1.88	1.92	1.95	0.037	0.45	0.22	0.83
F/G	1.59	1.63	1.65	0.029	0.37	0.18	0.65

[a]One hundred and eighty (PIC line C22 × 326, initially 20.1 lb and 35 day of age) were used with six pigs per pen and 10 replications (pens) per treatment.
[b]The maximum angle in degrees at which a pile of material retains its slope. The higher the value the poorer the flowability.

Table 2. Effects of Solvent Extracted Soybean Meal Particle Size on Growth Performance (Exp. 2)

	Soybean Meal Particle Size, Microns				P Values		
Item	444	797	1,226	SEM	Treatment	Linear	Quadratic
Angle of repose[b]							
Soybean meal	38.52	30.68	30.85	—	—	—	—
Diet	53.43	57.20	53.80	—	—	—	—
Diet particle size	629	681	732	—	—	—	—
Day 0 to 21							
ADG, lb	1.06	1.07	1.06	0.21	0.90	0.87	0.68
ADFI, lb	1.62	1.63	1.62	0.27	0.93	0.96	0.70
F/G	1.53	1.52	1.52	0.13	0.85	0.60	0.82

[a]One hundred and eighty (PIC line C22 × 326, initially 21.7 lb and 35 day of age) were used with six pigs per pen and 10 replications (pens) per treatment.
[b]The maximum angle in degrees at which a pile of material retains its slope. The higher the value the poorer the flowability.

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THE OPTIMAL RATIO OF APPARENT DIGESTIBLE VALINE TO LYSINE TO MAXIMIZE GROWTH PERFORMANCE OF THE NURSERY PIG

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

Summary

A total of 210 nursery pigs (initially 19.6 lb and approximately 28 d of age) were used in a 21-d growth assay to determine the optimal ratio of valine to lysine to maximize growth performance. The seven treatments consisted of a basal diet (14.2% CP; 1.07% apparent digestible lysine) with increasing ratios of valine:lysine (48, 53, 58, 63, 69, and 74%) and a negative control containing 0.97% lysine and 0.79% apparent digestible valine. Results indicate that the optimal apparent digestible valine:lysine ratio for the nursery pig is 58 and 64% for ADG and F/G, respectively. Therefore, most typical nursery diets will contain adequate amounts of valine to maximize growth performance of nursery pigs.

(Key Words: Valine, Lysine, Nursery Pigs.)

Introduction

Lysine, traditionally considered to be the first-limiting amino acid in young pig diets, has been intensively investigated. The methionine requirement for nursery pigs has also been thoroughly examined. However, research evaluating the requirements of other amino acids has been less extensive. Nutrient profiles of ingredients and amino acid requirements differ between the 1988 and 1998 NRC publications and have resulted in increases in the valine requirement for nursery pigs.

It has been reported that valine was as limiting as tryptophan, threonine, or methionine in a 13.5% protein, corn-soybean meal diet for 22 lb pigs. Further research suggested that the true ileal digestible valine requirement for 22 to 44 lb pigs was 75 and 71% of lysine for ADG and F/G, respectively. This estimate is higher than proposed by the NRC (1998), suggesting more research is warranted. The objective of this experiment was to determine the optimal ratio of valine to lysine in diets to maximize growth performance of the nursery pig.

Procedures

Two hundred ten (Line 327 sire × C22 dams; PIC) nursery pigs with an average initial weight of 19.6 lb and 28 d of age were used in a 21-d growth assay. Pigs were blocked by initial weight and ancestry and allotted randomly to each of the seven dietary treatments. Each treatment had six replications (pens) and five pigs per pen.

Corn, soybean meal, and spray-dried whey were analyzed for amino acid concentrations before diet formulation. The analyzed total amino acid levels and the apparent amino acid digestibility percentages from NRC (1998) were used to calculate the apparent digestible amino acid levels in each ingredient for diet formulation. Diets were corn-soybean meal-based and contained 8% spray-dried whey and 1.78% L-lactose (Table 1). Crystalline L-valine was added to the basal diet (1.07% apparent digestible lysine, 14.2% CP) to provide 48, 53, 58, 63, 69, and 74% apparent digestible valine:lysine. All amino acids, except valine, were formulated to meet or exceed the recommended NRC

[1]Food Animal Health and Management Center.

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requirements (Table 2). The negative control diet contained less L-lysine·HCl to provide 0.97% apparent digestible lysine and 0.81 apparent digestible valine:lysine to ensure that lysine was not above the pigs' requirement in the experimental diets. All diets were fed in meal form.

Pigs were housed in an environmentally controlled nursery. Temperature was maintained at 90°F for the 1st week and reduced by 5°F each week to maintain pig comfort. Each pen (4 ft^2 with slatted metal flooring) contained a stainless steel self-feeder and one nipple waterer to allow ad libitum consumption of feed and water.

Table 1. Basal Diet Composition (as-fed basis)[a]

Ingredient	%
Corn	66.92
Cornstarch[b]	0.28
L-lactose	1.78
Dried whey	8.00
Soybean meal (46.5% CP)	14.52
Choice white grease	3.00
Monocalcium phosphate (21% P)	1.05
Medication[c]	1.00
Zinc oxide	0.25
Limestone	1.00
Vitamin premix	0.30
Salt	0.30
Trace mineral premix	0.15
L-lysine·HCl	0.67
DL-methionine	0.17
L-threonine	0.26
L-isoleucine	0.17
L-phenylalanine	0.09
L-tryptophan	0.06
L-histidine·HCl	0.03

[a]Diet was formulated to 48% apparent digestible valine:lysine with all other amino acids meeting or exceeding 1998 NRC requirements. [b]L-Valine replaced cornstarch to provide 0.51, 0.57, 0.62, 0.68, 0.73, 0.79, and 0.79% apparent digestible valine. This provided apparent digestible valine:lysine ratios of 48, 53, 58, 63, 69, 74, and 81%. [c]Provided 55 mg/kg carbadox.

Table 2. Calculated Composition of Basal Diet[a,b]

Item	%
CP (N × 6.25)	14.17
Calcium	0.69
Phosphorus	0.57
Total	
Arginine	0.78
Histidine	0.55
Isoleucine	0.71
Leucine	1.34
Lysine	1.21
Methionine	0.42
Phenylalanine	0.75
Threonine	0.79
Tryptophan	0.22
Valine	0.63
Apparent digestible	
Arginine	0.68
Histidine	0.34
Isoleucine	0.61
Leucine	1.15
Lysine	1.07
Methionine	0.38
Phenylalanine	0.64
Threonine	0.65
Tryptophan	0.18
Valine	0.51
True digestible[c]	
Arginine	0.71
Histidine	0.35
Isoleucine	0.64
Leucine	1.21
Lysine	1.12
Methionine	0.39
Phenylalanine	0.68
Threonine	0.70
Tryptophan	0.20
Valine	0.54

[a]Values were calculated from analyzed composition of corn, soybean meal, and spray-dried whey.
[b]All amino acids in the negative control diet were the same with the exception of decreased lysine (1.07 vs 0.97% apparent digestible lysine).

Experimental diets were fed for 21 d. Pigs were weighed and feed disappearance measured every 7 d during the experiments to determine ADG, ADFI, and F/G. Blood samples were obtained by venipuncture on d 14 from two randomly selected pigs in each pen following a 3-h period of feed deprivation. Plasma urea N (PUN) determination was performed on each sample. Plasma from

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pigs in the same pen was pooled for amino acid analysis.

Data were analyzed in a randomized complete block design using the GLM procedures of SAS with pen as the experimental unit. Linear and quadratic polynomial contrasts were performed to compare the effects of increasing dietary valine. Contrasts were performed to compare the negative control to the diet containing the same level of apparent digestible valine (1.07% vs 0.97% apparent digestible lysine). In each experiment, one-slope and two-slope, broken-line regression models were used to estimate the requirement of valine to lysine. These ratios were estimated from the response curves of the least squares means.

Results and Discussion

Pigs fed the negative control diet gained less ($P<0.03$) when compared with pigs fed the diet containing the same level of valine (0.79% apparent digestible valine) and 1.07% apparent digestible lysine (Table 3). Average daily gain and ADFI increased with increasing valine and were maximized at 58% apparent digestible valine to lysine. Feed efficiency was improved with increasing valine and was best for pigs fed diets containing 63% apparent digestible valine to lysine.

Plasma urea N, measured on d 14, decreased and then increased (quadratic, $P<0.01$) with increasing apparent digestible valine (Table 4). Pigs fed the diet containing 58% apparent digestible valine to lysine had the lowest PUN concentration.

Plasma valine concentration increased (linear, $P<0.01$) with increasing dietary valine. The greatest response occurred as apparent digestible valine increased from 63 to 69% of lysine. The plasma lysine concentration was different ($P<0.01$) for pigs fed varying levels of apparent digestible valine; however, no linear or quadratic ($P>0.44$) effects were observed. Plasma methionine, tyrosine, phenylalanine, and histidine concentrations decreased (linear, $P\leq0.02$) with increasing levels of dietary valine; however, plasma isoleucine concentration increased (linear, $P<0.01$) with increasing levels of dietary valine.

The broken-line method (Table 5) predicted an apparent digestible valine requirement of approximately 54% of lysine for ADG and F/G using the one-slope model. The two-slope model predicted a requirement of approximately 55 and 64% of lysine for ADG and F/G, respectively.

The results of our experiment suggest that the apparent digestible valine:lysine ratio for 22- to 44-lb pigs is approximately 58%. This ratio is lower than the requirement suggested by the NRC (1998) and suggests that typical nursery diets used in commercial production will contain adequate amounts of valine.

Table 3. Effect of Apparent Digestible Valine:Lysine Ratio on Growth Performance of the Nursery Pig[a,b]

	Apparent Digestible Lysine, %											
	1.07						0.97					
	Valine, % of lysine								Probability (P<)			
Item	48	53	58	63	69	74	81	SEM	Lys	Val	Linear	Quad
ADG, lb	0.45	0.75	0.84	0.84	0.83	0.81	0.73	0.03	0.03	0.01	0.01	0.01
ADFI, lb	1.01	1.47	1.63	1.57	1.56	1.57	1.47	0.05	0.17	0.01	0.01	0.01
F/G	2.24	1.96	1.94	1.87	1.88	1.94	2.01	0.05	0.34	0.01	0.01	0.01

[a]Initial BW, 19.6 lb.

[b]Values are means of six replications (pens) and five pigs per pen for the 21-d experiment.

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Table 4. Effect of Apparent Digestible Valine:Lysine Ratio on Plasma Amino Acid Profile and PUN of the Nursery Pig[a]

	Apparent Digestible Lysine, %											
	1.07						0.97					
	Valine, % of lysine								Probability (P<)			
Item, µm/L	48	53	58	63	69	74		SEM	Lys	Val	Linear	Quad
Valine	62	86	140	255	378	490	357	26.00	0.01	0.01	0.01	0.01
Arginine	83	70	81	82	82	78	78	5.52	0.95	0.76	0.82	0.98
Histidine	76	53	49	50	49	48	52	5.26	0.55	0.01	0.01	0.01
Isoleucine	94	116	125	138	178	147	170	13.75	0.20	0.01	0.01	0.20
Leucine	164	179	177	182	170	153	203	11.45	0.01	0.06	0.46	0.06
Lysine	228	228	207	235	209	199	108	26.79	0.01	0.02	0.44	0.76
Methionine	54	42	42	41	40	40	44	4.12	0.53	0.14	0.02	0.12
Phenylalanine	77	71	66	64	62	63	74	3.70	0.03	0.02	0.01	0.12
Threonine	567	433	609	548	568	777	430	80.84	0.01	0.04	0.03	0.10
Tryptophan	45	44	41	44	39	41	44	2.82	0.43	0.69	0.20	0.69
Tyrosine	91	85	75	82	73	69	69	6.92	0.99	0.14	0.02	0.82
PUN, mg/dL	2.86	1.26	1.22	1.38	1.25	1.48	1.64	0.27	0.67	0.01	0.01	0.01

[a]Values are means of six replications (pens) of individual samples from two pigs per pen for PUN concentration and pooled samples from two pigs per pen for plasma amino acid concentrations.

Table 5. Predicted Apparent Digestible Valine:Lysine Requirement from Break-Point Analysis

Item	One-Slope[a]	Two-Slope[b]
ADG	54.3	54.6
ADFI	54.2	54.6
F/G	53.9	63.7
Plasma amino acids		
Valine	-	56.1
Lysine	-	63.0
PUN, mg/dL	52.7	63.3

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

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THE OPTIMAL THREONINE:LYSINE RATIO TO MAXIMIZE GROWTH PERFORMANCE OF NURSERY PIGS

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

Summary

A total of 210 pigs (initially 18.2 lb and 25 d of age) were used in a 21-d growth assay. The seven treatments consisted of a basal diet (14.1% CP) with increasing levels of threonine (45, 50, 55, 60, 65, and 70% of 1.07% apparent digestible lysine) and a negative control containing 0.97% lysine. Increasing dietary threonine improved feed efficiency; however, there was no improvement in growth performance between pigs fed 0.97 and 1.07% apparent digestible lysine. Therefore, these results suggest the requirement for apparent digestible threonine is approximately 60% of lysine for 18- to 40-lb pigs.

(Key Words: Threonine, Lysine, Nursery Pigs.)

Introduction

The current NRC (1998) requirements for a 22- to 44-lb pig suggest an apparent digestible threonine:lysine ratio of 60%. Because many practical diets used in the swine industry contain less than 60% apparent digestible threonine:lysine, supplementation of threonine to nursery diets has increased in recent years. The objective of this experiment was to determine the optimal ratio of threonine to lysine in diets to maximize growth performance of nursery pigs.

Procedures

Pigs were weaned at an average age of 21 d and fed a common diet for 7 d prior to the experimental diets. Pigs were housed in an environmentally controlled nursery. Temperature was maintained at 90°F for the 1st week and reduced by 5°F each week to maintain pig comfort. Each pen (4 ft^2 with slatted metal flooring) contained a stainless steel self-feeder and one nipple waterer to allow ad libitum consumption of feed and water.

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

Corn, soybean meal, and spray-dried whey were analyzed for amino acids before diet formulation. The analyzed total amino acid levels and the apparent amino acid digestibility percentages from NRC (1998) were used to calculate the apparent digestible amino acid levels in each ingredient for diet formulation. Diets were corn-soybean meal-based and contained 8% spray-dried whey and 1.78% L-lactose (Table 1). Crystalline L-threonine was added to the basal diet (1.07% apparent digestible lysine; 14.1% CP) to provide 0.45, 0.50, 0.55, 0.60, 0.65, and 0.70 apparent digestible threonine:lysine. The negative control diet contained less L-lysine·HCl to provide 0.97% apparent digestible lysine and 0.77

[1]Food Animal Health and Management Center.

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apparent digestible threonine:lysine to ensure that lysine was not above the pigs' requirement in the experimental diets. All other amino acids were formulated to 110% of the NRC (1998) requirements (Table 2). Diets were fed in meal form.

Data were analyzed in a randomized complete block design using the GLM procedures of SAS with pen as the experimental unit. Linear and quadratic polynomial contrasts were performed to determine the effects of increasing dietary threonine. Contrasts were performed to compare the negative control to the diet containing the same level of apparent digestible threonine (1.07% vs. 0.97% apparent digestible lysine). One-slope and two-slope, broken-line regression models were used to estimate the requirement of threonine to lysine. These ratios were estimated from the response curves of the least squares means.

Table 1. Basal Diet Composition (as-fed basis)[a]

Ingredient	%
Corn	66.41
Cornstarch[b]	0.27
L-lactose	1.78
Dried whey	8.00
Soybean meal (46.5% CP)	15.00
Choice white grease	3.00
Monocalcium phosphate (21% P)	1.05
Medication[c]	1.00
Zinc oxide	0.25
Limestone	1.00
Vitamin premix	0.30
Salt	0.30
Trace mineral premix	0.15
L-lysine·HCl	0.65
L-valine	0.23
DL-methionine	0.17
L-threonine	0.08
L-isoleucine	0.17
L-phenylalanine	0.09
L-tryptophan	0.06
L-histidine·HCl	0.04

[a]Diet was formulated to 45% apparent digestible threonine:lysine with all other amino acids meeting or exceeding 1998 NRC requirements.
[b]L-Threonine replaced cornstarch to provide 0.48, 0.54, 0.59, 0.64, 0.70, 0.75, and 0.75% apparent digestible threonine. This provided apparent digestible threonine:lysine ratios of 45, 50, 55, 60, 65, 70, and 77%.
[c]Provided 55 mg/kg carbadox.

Table 2. Calculated Composition of Basal Diet[a,b]

Item	%
CP (N × 6.25)	14.13
Calcium	0.69
Phosphorus	0.57
Total	
Arginine	0.81
Histidine	0.40
Isoleucine	0.71
Leucine	1.29
Lysine	1.21
Methionine	0.43
Phenylalanine	0.74
Threonine	0.61
Tryptophan	0.22
Valine	0.77
Apparent digestible	
Arginine	0.71
Histidine	0.34
Isoleucine	0.61
Leucine	1.12
Lysine	1.07
Methionine	0.40
Phenylalanine	0.64
Threonine	0.48
Tryptophan	0.18
Valine	0.73
True digestible[c]	
Arginine	0.73
Histidine	0.36
Isoleucine	0.63
Leucine	1.16
Lysine	1.12
Methionine	0.40
Phenylalanine	0.67
Threonine	0.51
Tryptophan	0.19
Valine	0.68

[a]Values were calculated from analyzed composition of corn, soybean meal, and spray-dried whey.
[b]All amino acids in the negative control diet were the same with the exception of decreased lysine (1.07 vs. 0.97% apparent digestible lysine).

Results

Pigs fed the negative control diet (0.97% apparent digestible lysine) had similar (P>0.10) growth performance as those fed

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0.70 apparent digestible threonine:lysine and 1.07% lysine (Table 3). Although there was not a significant (P<0.12) main effect response to threonine, we observed a linear increase (P<0.02) in ADG as dietary threonine increased. This response occurred because ADG was relatively similar for pigs fed threonine from 45 to 60% of lysine, but greatest for pigs fed threonine at 65% of lysine. Feed intake tended to decrease and then increase (quadratic, P<0.09) with increasing levels of apparent digestible threonine. Feed efficiency improved (linear, P<0.01) as the ratio of apparent digestible threonine:lysine increased and appeared to plateau between 55% and 60% of lysine.

Plasma urea N, measured on d 14, tended to decrease (linear, P<0.08) with increasing apparent digestible threonine (Table 4). The greatest response occurred as the apparent digestible threonine to lysine ratio increased from 45% to 50%.

Plasma threonine concentration increased (linear, P<0.01) with increasing dietary threonine. Plasma lysine concentration was not different (P>0.10) for pigs fed varying levels of apparent digestible threonine; however, pigs fed the negative control had a lower (P<0.01) plasma lysine concentration than pigs fed the higher lysine diet. Plasma leucine, tyrosine, phenylalanine, histidine, and arginine concentrations decreased (linear, P<0.04) with increasing levels of dietary threonine.

The one-slope broken-line method (Table 5) predicted an apparent digestible threonine requirement of 52% of apparent digestible lysine for F/G. The two-slope broken-line method also predicted an apparent digestible threonine requirement 52% of apparent digestible lysine for F/G.

Discussion

Because there was no response to our negative control diet, the apparent digestible lysine requirement of pigs in this experiment may have been closer to 0.97%. This would indicate that the actual threonine:lysine requirement should be calculated by the level of apparent digestible threonine needed to obtain maximum growth performance on a ratio to the level of lysine in the negative control (0.97% apparent digestible lysine) rather than 1.07% apparent digestible lysine. Feed efficiency and PUN appeared to be optimized close to 0.55 threonine:lysine. If we assume that the negative control (0.97% apparent digestible lysine) was closer to the actual lysine requirement, these results suggest an apparent digestible threonine requirement of 57% of lysine for F/G.

The results of our experiments suggest that the apparent digestible threonine:lysine ratio for 18- to 40-lb pigs is not more than approximately 60%. This ratio is similar to the requirement suggested by the NRC (1998).

Table 3. Effect of Apparent Digestible Threonine:Lysine Ratio on Growth Performance of the Nursery Pig[a,b]

	Apparent Digestible Lysine, %											
	1.07						0.97					
	Threonine, % of Lysine								Probability (P<)			
Item	45	50	55	60	65	70	77	SEM	Lys	Thr	Linear	Quad
ADG, lb	0.97	0.98	1.01	0.99	1.07	0.98	1.06	0.03	0.94	0.12	0.02	0.76
ADFI, lb	1.77	1.68	1.67	1.61	1.80	1.73	1.83	0.05	0.22	0.23	0.82	0.09
F/G	1.82	1.71	1.65	1.63	1.68	1.77	1.73	0.04	0.14	0.06	0.01	0.06

[a]Initial BW, 18.2 lb.

[b]Values are means of six replications (pens) and five pigs per pen for the 21-d experiment.

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Table 4. Effect of Apparent Digestible Threonine:Lysine Ratio on Plasma Amino Acid Profile and PUN of the Nursery Pig[a]

	Apparent Digestible Lysine, %											
	1.07						0.97					
	Threonine, % of Lysine								Probability (P<)			
Item	45	50	55	60	65	70	77	SEM	Lys	Thr	Linear	Quad
Amino acid, µm/L												
Threonine	77	173	256	591	674	959	1038	107.81	0.61	0.01	0.01	0.34
Arginine	128	96	104	82	92	92	95	8.40	0.78	0.02	0.01	0.06
Histidine	38	35	33	32	28	31	38	3.65	0.16	0.37	0.04	0.46
Isoleucine	139	145	148	135	142	131	158	7.61	0.02	5	0.35	0.35
Leucine	184	155	174	136	154	144	168	8.48	0.05	0.01	0.01	0.22
Lysine	213	238	206	232	217	226	138	23.90	0.01	0.10	0.90	0.96
Methionine	51	57	52	46	53	52	63	4.05	0.05	0.13	0.66	0.72
Phenylalanine	70	66	66	55	59	60	64	3.68	0.41	0.12	0.01	0.20
Tryptophan	49	46	48	44	45	45	49	2.70	0.31	0.69	0.22	0.54
Tyrosine	81	66	76	59	64	64	78	3.99	0.02	0.01	0.01	0.12
Valine	324	321	364	331	388	342	398	19.51	0.05	0.04	0.10	0.34
PUN, mg/dL	1.70	1.20	1.38	1.36	1.19	1.23	1.11	0.16	0.47	0.14	0.08	0.40

[a]Values are means of six replications (pens) of individual samples from two pigs per pen for PUN concentration and pooled samples from two pigs per pen for plasma amino acid concentrations.

Table 5. Predicted Apparent Digestible Threonine:Lysine Requirement from Break-Point Analysis

Item	One-Slope[a]	Two-Slope[b]
ADG	55.7	65.0
ADFI	48.3	57.8
F/G	52.1	52.4
PUN, mg/dL	64.4	65.2

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

[b]$Y = L + U(R-X_{LR}) + V(X_{GR}-R)$, where L = the ordinate of the breakpoint in the curve, R = the abscissa of the breakpoint 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.

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INFLUENCE OF DIETARY NIACIN ON STARTER PIG PERFORMANCE [1]

D. E. Real, J. L. Nelssen, M. D. Tokach, R. D. Goodband, S. S. Dritz [2], J. M. DeRouchey, B. W. James, E. Alonso [3]

Summary

Two experiments were conducted using 415 weanling pigs (175 in Exp. 1, 240 in Exp. 2) to determine the influence of dietary niacin inclusion on starter pig performance. Pigs were fed a control diet with no added niacin or the control diet with 25, 50, 75 or 100 g/ton of added niacin. From d 0 to 8, increasing dietary niacin increased ADG and ADFI up to 50 g/ton of added niacin. Overall, pigs fed increasing levels of niacin tended to have improved ADG. These results suggest feeding 50 g/ton of added dietary niacin to complex nursery pig diets to improve growth performance.

(Key Words: Niacin, Starter, Performance.)

Introduction

Niacin has long been accepted as an essential vitamin for swine diets; however, the optimal level of inclusion receives considerable debate. According to a 1997 survey of vitamin inclusion rates, the average inclusion rate for niacin was 39 g/ton. The average of the 25% of the companies with the highest inclusion rate was 61 g/ton. The average of the lowest 25% of the companies was 23 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. The most recent data published in the U.S. on niacin inclusion in starter diets found a linear increase in ADG through 90 g/ton. Due to the paucity of data concerning niacin requirements of nursery pigs and the wide range in supplementation rates in the commercial industry, we conducted this experiment to determine the influence of niacin level in nursery diets on starter pig performance.

Procedures

In Exp. 1, 175 weanling pigs (10.7 lb and 12 ± 2 days of age) were used in a 35d growth study. Pigs were housed in an environmentally regulated nursery in 4 × 4 ft pens at the Kansas State University Segregated Early Weaning facility. Pigs were provided ad libitum access to feed and water. Pigs were blocked by initial weight in a randomized complete block design. There were 7 replicate pens per treatment and each pen contained 5 pigs.

The trial was divided into four phases based on diet complexity (Table 1). The four phases were fed from d 0 to 4, d 4 to 8, d 8 to 22, and d 22 to 35. The first two diets were pelleted at the Kansas State University Grain Science Feed Mill using a 5/32 die and conditioned to 140°F. The last two diets were fed in meal form. Pigs were weighed and feed disappearance was determined to calculate ADG, ADFI, and F/G.

In Exp. 2, 240 pigs (initially 10.8 lb, 12 ± 2 d) were housed in a research facility on a commercial grower farm in NE Kansas.

[1]Authors thank Ken Anderson, Eichman Pork, Westmoreland, KS for pig management.
[2]Food Animal Health and Management Center.
[3]Lonza, Inc., Fair Lawn, NJ.

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There were 8 pigs per pen (5 × 5 ft) with 6 pens per treatment, and pigs were allowed ad libitum consumption of feed and water. Pens of pigs were randomly assigned to dietary treatments, similar to that in Exp. 1. Pigs were also fed similar diets and similar data were collected as in Exp. 1.

Data from both trials were pooled and analyzed as a randomized complete block design with pen as the experimental unit using the GLM procedure of SAS. The model included linear and quadratic contrasts for increasing dietary niacin levels.

Results and Discussion

From d 0 to 8, pigs fed increasing levels of niacin had improved ADG (quadratic, P<0.05) and ADFI (quadratic, P<0.02) with pigs fed 50 g/ton additional niacin having the greatest improvement in ADG (Table 3). From d 8 to 22, increasing niacin tended to improve F/G (quadratic, P<0.11). Overall (d 0 to 38), pigs fed increasing levels of niacin tended to have improved ADG (quadratic, P<0.12). There were no differences (P>0.21) in overall ADFI or feed efficiency.

The niacin in corn is unavailable to the pig, while niacin from soybean meal, is highly available. Excess dietary tryptophan can also be converted to niacin by pigs. The diets fed in this experiment were formulated to exceed the pigs' requirement for tryptophan (Table 2). When calculating the available niacin from the basal diet including the potential niacin from tryptophan, the diets fed from d 0 to 22 were similar to the niacin requirement estimate (NRC, 1998). However, because feed intake was very low from d 0 to 8, increasing niacin improved growth performance. Therefore, these results suggest that nursery pigs require 25 to 50 g/ton of added niacin to improve growth performance.

Table 1. Composition of Basal Diets

Ingredient, %	D 0 to 4[a]	D 4 to 10[a]	D 10 to 24[b]	D 24 to 38[b]
Corn	33.06	39.70	48.66	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 phosphate (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[e]	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[f]	0.15	0.15	0.15	0.15

[a]Fed in pelleted form. [b]Fed in meal form. [c]Provided 55 ppm carbadox from d 0 to 24 and 28 ppm from d 24 to 38. [d]Cornstarch was replaced by niacin (wt/wt) to provide supplemental niacin levels of 0, 25, 50, 75, 100 g/ton. [e]Vitamin premix provided 11,000 USP units vitamin A, 1,650 USP units vitamin D_3, 40 IU vitamin E, 4.4 mg vitamin K, 44 µg B_{12}, 10 mg riboflavin, and 33 mg pantothenic acid per kg of diet. [f]Trace mineral premix provided 165 mg zinc, 165 mg iron, 40 mg manganese, 17 mg copper, 0.30 mg iodine, and 0.30 mg selenium per kg of diet.

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Table 2. Available Niacin Content of Basal Diets

Item, mg/kg	D 0 to 4	D 4 to 10	D 10 to 24	D 24 to 38
Total basal diet[a]	20.7	19.5	22.6	22.8
From corn[b]	(7.9)	(9.5)	(11.8)	(13.6)
Total available[c]	12.8	10.0	10.8	9.2
From excess tryptophan[d]	8.2	3.6	2.4	10.0
Total niacin	20.0	13.6	13.2	19.2
Requirement[e]	20.0	15.0	12.5	10.0

[a]Analyzed values.
[b]Calculated from NRC (1998).
[c]Available niacin in basal diet excluding corn.
[d]Potential niacin from excess tryptophan over requirement (NRC, 1998).
[e]NRC (1998).

Table 3. Effects of Increasing Niacin on Nursery Pig Growth Performance[a]

	Niacin, g/ton						Contrasts, (P<)		
Item	0	25	50	75	100	SEM	Trt[b]	Linear	Quadratic
D 0 to 8									
ADG, lb	0.28	0.27	0.32	0.30	0.28	0.021	0.36	0.80	0.05
ADFI, lb	0.33	0.33	0.36	0.36	0.33	0.017	0.13	0.61	0.02
F/G	1.21	1.29	1.15	1.26	1.27	0.061	0.54	0.33	0.39
D 8 to 22									
ADG, lb	0.62	0.66	0.66	0.61	0.63	0.021	0.46	0.22	0.22
ADFI, lb	0.89	0.90	0.91	0.84	0.88	0.025	0.75	0.88	0.56
F/G	1.44	1.38	1.40	1.38	1.43	0.032	0.34	0.11	0.26
D 22 to 35									
ADG, lb	1.15	1.13	1.15	1.17	1.17	0.035	0.58	0.92	0.20
ADFI, lb	1.56	1.58	1.55	1.55	1.54	0.059	0.54	0.90	0.22
F/G	1.36	1.40	1.35	1.33	1.32	0.024	0.93	0.97	0.69
D 0 to 35									
ADG, lb	0.75	0.75	0.77	0.75	0.75	0.022	0.48	0.72	0.12
ADFI, lb	1.02	1.04	1.02	1.00	1.00	0.034	0.56	0.95	0.21
F/G	1.37	1.37	1.34	1.34	1.34	0.016	0.74	0.37	0.68

[a]Values represent means of two trials (7 replicates with 5 pigs/pen in Exp. 1, and 6 replicates with 8 pigs/pen in Exp. 2) that have been pooled.
[b]No treatment × trial interactions (P>0.20).

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INTERACTIVE EFFECTS OF CARNITINE STATUS, DIETARY CARNITINE, AND ADDED FAT ON GROWTH PERFORMANCE OF WEANLING PIGS [1]

J. C. Woodworth, J. L. Nelssen, R. D. Goodband, M. D. Tokach, S. S. Dritz [2], K. Q. Owen [3], and J. Lopez [4]

Summary

Two experiments were conducted to determine the interactive effects of carnitine status (with or without carnitine in diets fed to sows in gestation and lactation), and added fat and dietary carnitine in nursery diets on growth performance of weanling pigs. Feeding sows diets containing carnitine in gestation and lactation had no effect on growth performance of their pigs through 27-d after weaning. A carnitine by fat interaction ($P<0.05$) was observed for ADFI from d 0 to 7 and ADG from d 0 to 27 in Exp. 1 with pigs fed carnitine and no added fat appearing to have the best performance. In Exp. 2, added carnitine had little effect on growth performance, whereas added fat improved feed efficiency. In conclusion, no benefit to growth performance was observed from adding both carnitine and fat to the diet of weanling pigs in these experiments.

(Key Words: Weanling Pigs, Carnitine, Fat.)

Introduction

L-carnitine is a vitamin-like compound needed for proper utilization of medium- and long-chain fatty acids. Previous research has shown that carnitine added to diets of nursery pigs improved feed efficiency in phase II and III. Feed efficiency has also been shown to improve linearly when fat is added to the diets of pigs. Research conducted at Oklahoma State University showed that dietary carnitine improved growth performance of weanling pigs when fat was also added to the diet; however, no beneficial response was observed when carnitine was fed alone.

Previous research conducted at Kansas State University showed that pigs farrowed from sows fed diets containing carnitine had improved carcass characteristics at slaughter compared to pigs from sows fed diets not containing carnitine. In that experiment no differences in weight gain were observed for the pigs from d 0 to 35 after weaning. The objectives of these experiments were to: 1) further determine the growth performance of pigs in the nursery that were farrowed from sows fed diets with or without carnitine and 2) further evaluate the interactive effects of dietary carnitine and/or fat on growth performance of weanling pigs.

Procedures

Animals and Facilities. Two experiments were conducted at the Kansas State University Swine Teaching and Research Center. Pigs (PIC line C22 × 326) were blocked by initial weight, equalized for sex and litter, and randomly allotted to their respective dietary treatments. Creep feed was not offered to the pigs during lactation. Pigs were housed in an environmentally controlled nursery in 4 × 5 ft pens with woven wire flooring and had ad libitum access to

[1]Appreciation is expressed to Lonza, Inc., Fair Lawn, NJ, for financial support of these experiments.

[2]Food Animal Health and Management Center.

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

[4]ADM-Animal Health and Nutrition, Quincy, IL.

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feed and water. Initial temperature of the nursery was 90°F and was lowered approximately 3°F each week thereafter. Pigs were weighed and feed disappearance was determined on d 7, 14, 21, and 27 after weaning to calculate ADG, ADFI, and feed to gain ratio (F/G).

Experiment 1. A total of 176 weanling pigs (initially 14.4 lb and 21 d of age) were used to determine the interactive effects of carnitine status (0 or 50 ppm of carnitine fed to sows in gestation and lactation diets), carnitine (0 vs. 50 ppm in nursery diets), and fat (0 vs. 6% in nursery diets) on growth performance. At weaning, pigs were allotted to one of four experimental treatments with four or five pigs per pen and five replications (pens) per treatment.

All experimental diets were fed in meal form. Diets (Table 1) were fed in two phases, d 0 to 7 and 7 to 27. Diets were formulated on an equal lysine:calorie basis and met or exceeded all NRC (1998) nutrient requirement estimates. The corn-soybean meal ratio was adjusted when diets contained added fat to equalize the lysine:calorie ratio. L-carnitine replaced cornstarch in the basal diet to form the experimental treatments.

Experiment 2. A total of 150 weanling pigs (initially 12.1 lb and 21 d of age) were used in a 27-d growth trial to determine the interactive effects of dietary carnitine (0 vs. 50 ppm) and fat (0, 3, and 6%). Pigs were farrowed from sows fed diets that did not contain carnitine. Pigs were allotted to one of six treatments with five pigs per pen and five replications (pens) per treatment. Diets were formulated similar to those described in Exp. 1.

Statistical Analysis. Data were analyzed as a randomized complete block design with pen as the experimental unit. Analysis of variance was performed using the Mixed procedure of SAS. The model included all main effects as well as two- or three-way interactions.

Results and Discussion

Experiment 1. No three-way interactions were observed for any response criteria measured. An interaction between fat and carnitine in the nursery diet was observed ($P<0.05$) for ADFI from d 0 to 7 and ADG from d 0 to 27. Pigs fed the diet containing carnitine and no fat had greater ADFI or ADG compared to pigs fed the diet not containing carnitine and no fat; however, when fat was added to the diet, no benefit from dietary carnitine was observed. A tendency for a fat x carnitine interaction was also observed ($P<0.10$) for ADG from d 7 to 27 and ADFI from d 7 to 27 and 0 to 27. Again, pigs fed diets containing carnitine and no fat had greater ADG or ADFI compared to diets containing no carnitine, but when fat was also added to the diet no carnitine effect was observed.

Throughout the entire experiment, no main effect ($P>0.10$) of carnitine status or dietary carnitine was observed. Dietary fat had no effect ($P>0.10$) on ADG or ADFI, but improved ($P<0.01$) F/G from d 0 to 7, 7 to 27 and 0 to 27.

Experiment 2. No fat × carnitine interactions were observed for any response criteria. Added fat or carnitine had no effect ($P>0.10$) on ADG or ADFI from d 0 to 7, 7 to 27, or 0 to 27. Pigs fed diets containing fat had improved ($P<0.03$) F/G compared to those fed diets not containing fat from d 7 to 27 and 0 to 27. Pigs fed diets containing carnitine had poorer ($P<0.05$) F/G compared to those fed diets not containing carnitine from d 7 to 27 and 0 to 27.

These results suggest that nursery growth performance of pigs farrowed from sows fed diets with or without carnitine are similar. Previous research conducted at Kansas State University showed that pigs farrowed from sows fed carnitine had heavier muscled carcasses at slaughter compared to pigs obtained from sows fed diets not containing carnitine. These researchers suggested the improvement in muscling was reflective of a greater number of muscle fibers present from the pigs obtained from the sows fed diets

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with carnitine, a factor that might not influence growth performance immediately after weaning, but may influence growth performance in the finishing phase (>120 lbs). Unfortunately, we were unable to determine the effects of maternal diet on growth performance in the finisher and carcass composition of pigs used in this experiment.

Contrary to our previous research and research conducted at Oklahoma State University, our experiment showed no benefit in growth performance when carnitine was added to diets containing fat. The Oklahoma State University researchers observed a greater response to carnitine when fat was also included in the diet compared to when diets contained no fat. Differences in diet formulation could account for the inconsistencies observed, because our diets were all balanced on an equal lysine:calorie, whereas the OSU diets were not. Also, because the body synthesizes carnitine from methionine and lysine, dietary carnitine may act to spare either of these amino acids if the diet is formulated to levels below the pig's requirement.

The inconsistent responses to growth performance from adding carnitine to the diets of weanling pigs are similar to those observed with other vitamins. The animal's demand for a vitamin is often dependent on the influence of factors such as basal dietary concentration of the vitamin, body storage of the vitamin, growth rate, and stress (health, temperature, etc.). Thus, the vitamin may not elicit a beneficial response to growth performance in every experiment in which it is tested, similar to dietary carnitine.

In conclusion, pigs obtained from sows fed diets containing carnitine will exhibit growth performance immediately after weaning similar to those obtained from sows fed diets without added carnitine. Carnitine added to nursery diets had little effect on growth performance of weanling pigs in these experiments. Including fat in the diets of weanling pigs improved feed efficiency, especially in the latter portion of this experiment. More research should be conducted to further define the interactive effects of dietary fat and carnitine on growth performance of weanling pigs.

Table 1. Diet Composition (As-Fed Basis)

	Day 0 to 7			Day 7 to 27		
Item, %	0% Fat	3% Fat[a]	6% Fat	0% Fat	3% Fat[a]	6% Fat
Corn	45.27	39.79	33.95	57.69	52.41	47.19
SBM (46.5% CP)	15.19	17.65	20.47	26.30	24.03	28.51
Dried whey	25.00	25.00	25.00	10.00	10.00	10.00
Spray-dried plasma	5.00	5.00	5.00	-	-	-
Select menhaden fish meal	6.00	6.00	6.00	4.50	4.50	4.50
Soy oil	-	3.00	6.00	-	3.00	6.00
Monocalcium phosphate (21% P)	0.75	0.75	0.75	1.05	1.05	1.05
Limestone	0.45	0.45	0.45	0.50	0.50	0.50
Salt	0.20	0.20	0.20	0.25	0.25	0.25
Vitamin premix	0.25	0.25	0.25	.025	.025	.025
Trace mineral premix	0.15	0.15	0.15	.015	.015	.015
Sow add pack	0.05	0.05	0.05	0.05	0.05	0.05
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00	1.00
Zinc oxide	0.38	0.38	0.38	0.25	0.25	0.25
L-threonine	0.03	0.04	0.05	0.04	0.045	0.05
L-lysine HCl	0.15	0.15	0.15	0.15	0.15	0.15
DL-methionine	0.08	0.09	0.10	0.04	0.045	0.05
Cornstarch[c]	0.05	0.05	0.05	0.05	0.05	0.05
Calculated Analysis						
Total lysine, %	1.55	1.61	1.68	1.30	1.36	1.41
ME, kcal/lb	1,477	1,538	1,599	1,477	1,539	1,600
Lysine:ME, g/mcal	4.76	4.75	4.76	3.99	3.99	3.99
Calcium %	0.88	0.89	0.90	0.79	0.80	0.80
Phosphorus, %	0.84	0.84	0.84	0.76	0.76	0.76

[a]Experiment 2 only. [b]Provided 50 g/ton carbadox. [c]Cornstarch was replaced with 50 ppm L-carnitine to form the experimental treatments.

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Table 2. Influence of Dietary Carnitine and/or Fat on Growth Performance of Weanling Pigs Obtained from Sows Fed Diets With or Without Carnitine, Exp. 1[a]

	Negative Carnitine Status[b]				Positive Carnitine Status[b]							
Carnitine, ppm:	0	50	0	50	0	50	0	50		Probability, P<		
Item Fat, %:	0	0	6	6	0	0	6	6	SEM	Status	Carnitine	Fat
Day 0 to 7												
ADG, lb	.53	.60	.65	.59	.53	.56	.60	.57	.04	.53	.88	.12
ADFI, lb[c]	.60	.68	.67	.62	.56	.60	.62	.59	.04	.22	.66	.64
F/G	1.14	1.14	1.03	1.06	1.06	1.07	1.04	1.02	.04	.10	.80	.01
Day 7 to 27												
ADG, lb[d]	.93	1.04	1.03	1.00	.94	.98	1.03	1.01	.05	.68	.37	.12
ADFI, lb[d]	1.37	1.56	1.40	1.36	1.41	1.45	1.43	1.43	.08	.87	.24	.32
F/G	1.47	1.51	1.37	1.36	1.50	1.48	1.40	1.42	.04	.41	.77	.001
Day 0 to 27												
ADG, lb[c]	.83	.93	.93	.89	.83	.87	.92	.90	.05	.57	.45	.10
ADFI, lb[d]	1.17	1.34	1.21	1.17	1.19	1.23	1.22	1.21	.07	.81	.27	.43
F/G	1.41	1.44	1.31	1.31	1.43	1.41	1.34	1.35	.03	.55	.71	.001

[a]A total of 176 pigs (initially 14.4 lb and 21 d of age) with four or five pigs per pen and five pens per treatment. [b]Negative carnitine status refers to pigs farrowed from sows fed diets not containing carnitine and positive carnitine status refers to pigs farrowed from sows fed diets containing 50 ppm carnitine in the previous gestation and lactation. [c]Fat × carnitine, (P<0.05). [d]Fat × carnitine, (P<0.10).

Table 3. Interactive Effects of Dietary Fat and L-carnitine on Growth Performance of Weanling Pigs, Exp. 2[a]

	Fat, %:	0	0	3	3	6	6		Significance, P<		
Item	Carnitine,	0	50	0	50	0	50	SEM	Fat	Carnitine	Fat × Carn.
Day 0 to 7											
ADG, lb		0.62	0.61	0.65	0.60	0.60	0.68	0.03	0.72	0.90	0.13
ADFI, lb		0.72	0.74	0.77	0.72	0.75	0.80	0.05	0.71	0.90	0.60
F/G		1.16	1.22	1.18	1.20	1.25	1.20	0.05	0.72	0.81	0.48
Day 7 to 27											
ADG, lb		0.88	0.93	0.96	0.90	0.96	0.96	0.04	0.37	0.99	0.30
ADFI, lb		1.36	1.45	1.41	1.40	1.38	1.42	0.06	0.98	0.29	0.59
F/G		1.54	1.56	1.47	1.56	1.45	1.48	0.03	0.007	0.04	0.31
Day 0 to 27											
ADG, lb		0.81	0.85	0.88	0.82	0.86	0.89	0.04	0.39	0.97	0.29
ADFI, lb		1.20	1.27	1.24	1.23	1.22	1.26	0.05	0.99	0.38	0.58
F/G		1.47	1.50	1.41	1.49	1.41	1.42	0.02	0.03	0.05	0.30

[a]Values represent a total of 150 pigs (initially 12.1 lb and 21 d of age) with five pigs per pen and five pens per treatment.

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EFFECTS OF FEEDING GRADED LEVELS OF RACTOPAMINE (PAYLEAN™) ON PIG PERFORMANCE IN A COMMERCIAL FINISHING FACILITY

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

Summary

A total of 880 pigs were used in a 21-day trial conducted in a commercial research facility to determine the influence of feeding graded levels (0, 4.5, 6.75, and 9.0 g/ton) of ractopamine HCl (Paylean™, Elanco Animal Health) on pig performance and carcass composition. Ractopamine supplementation improved ADG 17 to 22% and F/G 12 to 20%. Increasing ractopamine dosages resulted in improved F/G, but similar ADG. With the exception of a tendency to increase yield, carcass parameters were not different among treatments. Ractopamine supplementation resulted in improved economic returns ($2.55 to $3.20/pig), which were due to the improvements in carcass weights (80%) and lean premium (20%).

(Key Words: Ractopamine, Paylean, Economics.)

Introduction

Ractopamine is a feed additive approved in December 1999 for use in growing swine. This product is classified as a beta-adrenergic agonist. This product was well studied in the late 1980s during the initial phases of the approval process. Ractopamine supplementation has been demonstrated to improve lean accretion, feed conversion, and decrease fat deposition. Our objective was to determine the impact of feeding graded levels of ractopamine during the last 21 days of the finishing period. An economic analysis was completed to better understand potential effects on producer profitability.

Procedures

This experiment was completed in a commercial finishing research facility. Forty pens (20 barrow pens, 20 gilt pens) of pigs (PIC C22 x 337) were allotted to treatment with an average pig weight of 235 lb. Pens had totally slatted floors, were 10 × 18 ft, and contained 20 to 23 pigs per pen. Each pen was equipped with a 50-inch dry feeder (Staco) and cup waterer. This double curtain sided finishing barn is a deep-pitted facility.

The four dietary treatments were based on level of ractopamine (0, 4.5, 6.75, or 9.0 g/ton) added to the diet. Diets were corn-soybean meal-based with no added fat and included 3 lb/ton of synthetic lysine. The diets were formulated to 0.7 % and 0.9 % total dietary lysine, .54 % and .56% calcium, and 0.49 and 0.52% phosphorus for the control and ractopamine supplemented diets, respectively. Vitamin and trace mineral supplementation was similar across treatments.

Ten pens (5 barrow, 5 gilt) were assigned to each treatment and blocked based on average pig weight. On the day prior to allotment, the heaviest pigs had been removed from each pen. Pen weights were obtained at the beginning and end of the 21-day evaluation. Feed delivery was recorded daily, and feed remaining at the end of the trial was measured. Average daily gain,

[1]Food Animal Health and Management Center.

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ADFI, F/G and carcass composition were measured in this evaluation.

At the conclusion of the trial, pigs in each pen were identified with a unique tattoo to obtain carcass information on a pen basis. At slaughter, fat and loin depth were measured with an optical probe and used to calculate lean percentage. Fat, loin depth, and lean percentage were adjusted to a common carcass weight for statistical evaluation. Data were analyzed using GLM procedures of SAS in a randomized complete block design. An economic evaluation was completed using actual feed costs and carcass revenue information attained from the pens in this evaluation.

Results and Discussion

Ractopamine supplementation improved ($P<0.01$) ADG and F/G compared with those fed the control diet (Table 1). However, differences were not observed in ADG ($P>0.27$) among the three ractopamine treatments. Pigs fed 9.0 g/ton of ractopamine had improved F/G ($P<0.02$) compared to pigs fed the 4.5 g/ton, with pigs fed 6.75 g/ton having intermediate F/G. No differences in ADFI ($P>0.47$) were observed among treatments. Gender differences were not observed ($P>0.37$) in ADG or F/G in this 21-day evaluation. There was no gender × ractopamine interaction ($P>0.37$) for any of the parameters measured in this study.

Ractopamine supplementation did not affect ($P>0.49$) lean percentage, backfat, or loin depth (Table 1). However, a tendency for improvement in yield ($P<0.12$) was observed. Carcass weights were greater ($P<0.01$) for pigs fed ractopamine, regardless of level. However, no differences in carcass weight ($P>0.50$) were observed among pigs fed the 3 levels of ractopamine. Gender differences in lean percentage (54.5 vs. 56.2 ±0.3% for barrow vs. gilt, respectively; $P<0.01$) and backfat (0.76 vs.0.65 ±. 01 in; $P<0.01$) were observed.

Our economic evaluation used actual feed cost and carcass revenue information at the time the trial was performed. Sort loss was fixed, and carcass base price was $59.14 cwt. Diet costs including manufacturing and delivery costs increased due to both the increased lysine fortification and increasing levels of ractopamine (Table 2). Cost per lb of gain also was increased with the ractopamine-supplemented diets. Although feed cost increased, the margin over feed costs improved with the ractopamine treatments. Approximately 80% of the improved margin was due to the 5-lb increase in carcass weights of pigs fed ractopamine. The remaining 20% of the improvement was due to the numerical improvements observed in carcass lean, and the resulting increase in lean premium.

Feeding ractopamine at 4.5 to 9.0 g/ton for 21 days prior to slaughter improved ADG and F/G. Increasing dosages from 4.5 to 9.0 g/ton resulted in similar ADG, but improved F/G. Ractopamine supplementation 21 days prior to slaughter appears to be an opportunity to enhance producer profitability. Approximately 80% of the margin improvement in this study was due to the increased carcass weight. Therefore, feeding ractopamine offers the most opportunity to producers that are short of finishing space or selling pigs below an optimum market weight.

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Table 1. Effects of Ractopamine on Growth, Efficiency, and Carcass Performance

	Paylean™ g/ton				
Item	Neg	4.5 g	6.75 g	9.0 g	SE
Weight on test, lb	235.2	235.4	234.4	234	1.1
ADG, lb	1.69[b]	1.98[c]	2.00[c]	2.07[c]	0.07
ADFI, lb	6.14	6.18	6.00	5.96	0.11
F/G	3.57[b]	3.13[c]	2.94[c,d]	2.86[d]	0.1
Sale wt, lb	272.6[b]	278.2[c]	277.1[c]	278.9[c]	1.76
Avg. carcass wt, lb	207.0[b]	212.2[c]	212.0[c]	213.2[c]	1.3
% Yield[e]	75.7	76.2	76.3	76.6	0.23
Backfat[f], in	0.72	0.71	0.70	0.69	0.02
Loin depth[f], in	2.38	2.42	2.46	2.43	0.04
% Lean[f]	54.9	55.2	55.5	55.6	0.34

[a]A total of 40 pens (20 pens of barrows and 20 pens of gilts) were fed graded levels of ractopamine (Paylean™) during the last 21 days of the finishing period.
[b,c,d]Means in the same row without a common superscript differ (P<0.02).
[e]Yield was calculated using live carcass pen-weights attained at the slaughter plant.
[f]Backfat, loin depth and percent lean were adjusted to a common carcass weight.

Table 2. Economic Evaluation of Ractopamine Supplementation Fed 21 Days Prior To Slaughter[a]

	Paylean™ g/ton			
Item	Neg	4.5 g	6.75 g	9.0 g
Diet costs, $/ton[b]	$92.90	$109.97	$115.47	$120.96
Feed cost/lb of gain, $/lb[b]	$0.168	$0.172	$0.172	$0.174
Added revenue due to carcass weight[cd]		$3.10	$3.02	$3.73
Added revenue due to lean premium[cd]		$0.55	$0.73	$1.01
Added feed costs[bd]		$1.09	$1.07	$1.55
Margin advantage[d]		$2.55	$2.68	$3.20

[a]This economic evaluation was completed using actual feed costs and carcass revenue information attained from this evaluation.
[b]Cost information: corn,$1.85/bu; SBM 46.5%, $150/ton; feed manufacturing and delivery, $ 12/ton.
[c]Revenue information: carcass base price, $59.74/cwt; sort loss was fixed across treatments; lean premium, Swift, Inc (Worthington, MN) lean premium grid at the time of sale.
[d]Added revenue, added cost, and margin advantage information are all in comparison to the negative control group.

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INTERACTIVE EFFECTS BETWEEN PAYLEAN™ (RACTOPAMINE HCL) AND DIETARY LYSINE ON FINISHING PIG GROWTH PERFORMANCE, CARCASS CHARACTERISTICS AND TISSUE ACCRETION [1]

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Summary

A total of 432 pigs were used to evaluate the effects of Paylean and dietary lysine on finishing pig growth performance, carcass characteristics and tissue accretion. The 12 dietary treatments included Paylean (0, 4.5, and 9.0 g/ton) and 4 levels of lysine. For pigs fed no Paylean, lysine levels were 0.60, 0.80, 1.00, and 1.20%. For pigs fed 4.5 or 9.0 g/ton of Paylean, lysine levels were 0.80, 1.00, 1.20, and 1.40%. The results indicate that pigs fed Paylean need at least 1.0% dietary lysine to optimize growth, carcass parameters, and tissue accretion.

(Key Words: Paylean, Lysine, Finishing Pigs, Accretion.)

Introduction

In 1999, the FDA approved Paylean to be used in finishing pig diets. Extensive research has shown that Paylean improves growth performance and carcass leanness by directing nutrients away from fat deposition and toward protein deposition. To support the increased protein deposition, it is very likely that dietary lysine concentrations will need to be increased. Therefore, the objective of this experiment was to evaluate the interactive effects of dietary lysine and Paylean dosage on finishing pig growth performance, carcass characteristics, and tissue accretion.

Procedures

Four hundred thirty-two pigs (PIC 326 × C22) averaging 175 lb were used in this experiment. The experiment was divided into two identical trials, the first beginning in October 2000, and the second starting in February 2001. Procedures were identical for both trials. Pigs were housed with three per pen and 12 pens (5 × 5 ft) per treatment (six pens of barrows and six pens of gilts) in a randomized complete block design. Pigs were blocked by initial weight and sex, and then randomly allotted to one of the 12 experimental treatments. Feed and water were provided ad libitum.

The experiment was arranged in an incomplete 3 × 4 factorial. Main effects included Paylean dosage (0, 4.5 and 9 g/ton) and dietary lysine. Control diets contained 0.60, 0.80,1.00, and 1.20% total lysine and for pigs fed Paylean, diets contained 0.80, 1.00, 1.20, and 1.40% total lysine (Table 1). Dietary treatments were fed for four weeks from approximately 175 to 240 lb. The primary difference in the diet formulation among treatments was an adjustment in the corn:soybean meal ratio. Amino acid ratios were maintained in all diets to ensure lysine was first limiting (NRC, 1998). Complete diets were sampled and analyzed for dry matter, crude protein, and Paylean.

Pigs were weighed and feed disappearance determined every 7 days during the 28

[1]The authors wish to thank Elanco Animal Health, a division of Eli Lilly Corporation, Indianapolis, IN, for partial funding of the experiment.

[2]Food Animal Health and Management Center.

[3]Elanco Animal Health, Indianapolis, IN.

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d experiment. At the beginning of the trial, pigs were randomly assigned either to mid-point slaughter (d 14), ending slaughter (d 28) or as an alternate in case a pig was removed due to death, sickness, or being 2 standard deviations from treatment mean.

One pig per pen was processed at the KSU Meat Lab on d 14 (midpoint) and 28 (end) of the trial. At 24 hours postmortem, carcass parameters were measured on the right side of the carcass. Average backfat (first rib, last rib, and last lumbar), tenth rib fat depth, longissimus muscle area, and carcass weight were determined.

Daily accretion rates of moisture, crude protein, fat, and ash were also determined. At the start of each trial, six randomly selected pigs (equal number of each sex) were slaughtered. At 24 hours postmortem, the left side from each carcass was allowed to freeze in a blast freezer for approximately 1.5 h. After freezing, sides were ground once through a meat grinder equipped with a 3/4 inch die then ground twice through a second meat grinder equipped with a 3/8 inch die. A subsample of ground carcass was then chemically analyzed to determine percentages of crude protein, moisture/dry matter, lipid and ash. This procedure was then repeated on the left side of each carcass of all pigs slaughtered on d 14 and 28 of the study.

Carcass accretion rates were calculated by multiplying the percentages of moisture, protein, lipid and ash determined in the initial 12 pigs slaughtered at the start of the study by their chilled carcass weight. Percentages of moisture, protein, lipid and ash were then determined in the pigs slaughtered on d 14 and 28 and multiplied by their respective cold carcass weights. The values at the start of the study were subtracted from those on d 14 and 28 and divided by 14 and 28 to calculate a daily carcass accretion rate.

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 polynominal contrasts were performed to determine the effects of increasing levels of dietary lysine within each Paylean level and increasing levels of Paylean.

Results

Growth Performance. From d 0 to 14, a trial × treatment interaction ($P<0.01$) was observed for ADG and F/G (Table 2). The interaction occurred because we observed an improvement in ADG and F/G with increasing lysine among control pigs in Trial 1 but not in Trial 2. Also, in Trial 2, ADG, and F/G was poorer for pigs fed 9.0 g/ton Paylean and 1.4% lysine than those fed 1.2% lysine, but in Trial 1, pigs fed 1.4% lysine and 9.0 g/ton Paylean had similar growth performance to those fed 1.2% lysine. Despite these interactions, there was an improvement (quadratic, $P<0.04$) in ADG and F/G as Paylean increased. For pigs fed 4.5 and 9.0 g/ton of Paylean, there was a decrease (linear, $P<0.02$) in ADFI as lysine increased. Increasing lysine improved (quadratic, $P<0.007$) F/G at each Paylean level.

For the overall growth trial, as Paylean increased, there was an increase (quadratic, $P<0.003$) in ADG. Furthermore, increasing dietary lysine tended to increase ADG (linear, $P<0.09$) and improved (linear, $P<0.01$) F/G in control pigs. For pigs fed Paylean, increasing dietary lysine increased and improved (quadratic, $P<0.07$ and $P<0.04$, respectively) ADG and F/G. Also, for pigs fed Paylean, increasing dietary lysine decreased (linear, $P<0.05$) ADFI.

Carcass Characteristics. For carcass data collected from pigs slaughtered on d 14 of the study (Table 3), several trial*sex interactions were observed. However, these interactions were due to a difference in the magnitude of response between the barrows and gilts when comparing the two trials. In general, we observed greater differences between gilts and barrows in Trial 2 than we did in Trial 1. These parameters included cold carcass weight, tenth rib backfat, last rib backfat, and average backfat thickness. In addition, there was a significant trial × treatment interaction for average backfat. For pigs fed 9.0 g/ton of Paylean, increasing lysine decreased backfat thickness in Trial 1;

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however, there was a slight increase in backfat thickness with increasing lysine in Trial 2.

As Paylean dosage increased, there was an increase (linear, P<0.01) in cold and hot carcass weight and decreased (linear, P<0.02) leaf fat. Pigs fed the control diet had a decrease (linear, P<0.05) in first rib backfat as dietary lysine increased.

For the carcass data collected from pigs slaughtered on d 28 (Table 4), there were several trial × sex interactions. Similar to the midpoint carcass data, these interactions were magnitude differences observed between barrows and gilts in the two trials. The parameters affected included cold carcass weight, leaf fat, and, tenth rib backfat.

Pigs fed increasing Paylean had a increase (linear, P<0.0003) in live weight, percentage yield, hot, and cold carcass weights. Furthermore, as Paylean levels increased, leaf fat, tenth rib backfat, and average backfat thickness decreased (linear, P<0.01). As Paylean increased, lean percentage and loin eye area increased (linear, P<0.01). At 4.5 g/ton of Paylean, pigs had decreased (quadratic, P<0.04) live, hot, and cold carcass weight as dietary lysine increased. In pigs fed 4.5 g/ton of Paylean, leaf fat and tenth rib backfat decreased (linear, P<0.01) and lean percentage and loin eye area increased (quadratic, P<0.05) with increasing dietary lysine. For pigs fed Paylean, there was a decrease (linear, P<0.03) in average backfat thickness as lysine increased. For pigs fed 4.5 g/ton of Paylean, there was a increase (quadratic, P<0.05) in lean percentage and loin eye area as the lysine levels increased.

Tissue Accretion. A trial × treatment interaction was observed from d 0 to 14 tissue accretion data (Table 5) because moisture accretion was lower for pigs fed 0.6% lysine and no Paylean in Trial 1 than in Trial 2.

On d 14, as Paylean increased, the percentage moisture and protein increased (linear, P<0.03) and fat percentage decreased (linear, P<0.03). This agrees with the tissue accretion in the first two weeks. From d 0 to 14, as Paylean increased, there was an increase (linear, P<0.0001) in protein and moisture accretion. In pigs fed no Paylean, moisture accretion increased (quadratic, P<0.01) as dietary lysine increased. Also, in pigs fed 9.0 g/ton of Paylean, the moisture accretion increased (linear, P<0.04) as lysine increased. There were no differences in fat accretion from d 0 to 14 for any of the treatments. However, for control pigs (no Paylean), protein accretion increased (linear, P<0.005 and quadratic, P<0.04) as lysine levels increased.

From d 0 to 28, as Paylean increased, there was an increase (linear, P<0.0001 and quadratic, P<0.02, respectively) in protein and moisture accretion. Also, as Paylean increased, there was a decrease (linear, P<0.01) in fat accretion. Additionally, by adding Paylean or lysine to the diet, there was an increase (linear, P<0.02 and P<0.01, respectively) in moisture and protein percentages and a decrease (linear, P<0.03) in fat percentage.

In pigs fed 4.5 g/ton of Paylean, moisture accretion increased (linear, P<0.03) and protein accretion increased (quadratic, P<0.03) as lysine increased. Also, in Paylean fed pigs, fat accretion decreased (linear, P<0.03) as lysine increased.

Discussion

The results from this experiment suggest that in the first two weeks and the overall 28 d period, pigs fed Paylean (175 to 215 lb) gained weight considerably faster than control pigs. For control pigs, feeding at least 0.80% dietary lysine improved growth performance. It would appear that 1.0% lysine was sufficient for pigs fed 4.5 g/ton Paylean. However, from day 0 to 14 in pigs fed 9.0 g/ton Paylean, improvements in growth performance were observed through 1.2% lysine. This growth response agrees with the previous research that shows more lysine is required when pigs are fed Paylean, especially during the first two weeks that the Paylean is fed.

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During the first two weeks in pigs fed Paylean, leaf fat, last lumbar backfat, and average backfat decreased and loin eye area increased. The carcass characteristics at the end of the four-week trial had a more dramatic response to Paylean when compared to the response in carcass characteristics after the first two weeks.

For pigs fed Paylean, there was an increase in moisture and protein accretion in the first two weeks. For the overall trial, Paylean increased moisture and protein accretion and decreased fat accretion. This indicates that the response to Paylean during the first two weeks of feeding is an increase in muscle accretion. The predominant response during the last two weeks is a decrease in fat accretion. In the first two weeks, the only response to lysine levels was an increase in moisture and protein accretion in control pigs. However, the response in the last two weeks is that as the lysine increased, fat accretion decreased and protein accretion increased. This response indicates that pigs fed the highest lysine levels in all Paylean levels were the leanest.

In conclusion, Paylean increases growth performance by increasing lean gain and decreasing fat accretion. This results in a faster gaining, leaner pig. With the wide range of lysine levels used in our study, our data would suggest pigs fed Paylean require at least 1.0% dietary lysine.

Table 1. Diet Composition

	Dietary Lysine, %[a]				
Ingredient,%	0.60	0.80	1.00	1.20	1.40
Corn[b]	84.60	77.34	70.10	62.84	54.54
Soybean meal (47% CP)	12.60	19.86	27.12	34.37	42.63
Monocalcium phosphate (21% P)	1.15	1.15	1.10	1.05	1.00
Limestone	0.90	0.90	0.90	0.90	0.90
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
L-isoleucine	—	—	0.01	0.03	0.06
L-threonine	—	—	0.00	0.00	0.02
DL-methionine	—	—	0.02	0.06	0.10
Total	100.00	100.00	100.00	100.00	100.00
Calculated analysis					
Crude protein, %	13.2	16.0	18.8	21.7	24.5
Total lysine, %	0.60	0.80	1.00	1.20	1.40
True digestible lysine, %	0.51	0.70	0.88	1.06	1.24
ME, kcal/lb	1,506	1,504	1,503	1,502	1,500
Lysine:cal ratio, g/mcal	1.81	2.41	3.02	3.62	4.23
Calcium, %	0.62	0.65	0.66	0.67	0.69
Phosphorus, %	0.57	0.60	0.61	0.63	0.65
Available phosphorus, %	0.29	0.30	0.30	0.30	0.30

[a]Diets containing 0.60, 0.80, 1.00, and 1.20% lysine were fed to control pigs (no Paylean). Pigs fed 4.5 and 9.0 g/ton of Paylean had lysine levels of 0.80, 1.00, 1.20, and 1.40%.
[b]Paylean replaced corn to provide 4.5 or 9.0 g/ton.

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Table 2. Effects of Increasing Dietary Lysine and Paylean on Growth Performance of Finishing Pigs[a]

Paylean, g/ton:	0.0				4.5				9.0				
Lysine, %:	0.6	0.8	1.0	1.2	0.8	1.0	1.2	1.4	0.8	1.0	1.2	1.4	SEM
Day 0 to 14													
ADG, lb	2.08	2.25	2.35	2.24	2.42	2.72	2.66	2.53	2.51	2.70	2.85	2.69	0.07
ADFI, lb	6.68	6.75	6.53	6.50	6.97	6.85	6.55	6.38	7.02	6.81	6.78	6.52	0.14
F/G	3.26	3.01	2.80	2.92	2.91	2.53	2.47	2.53	2.82	2.54	2.38	2.45	0.07
Day 0 to 28													
ADG, lb	2.14	2.19	2.29	2.26	2.41	2.58	2.50	2.42	2.49	2.57	2.57	2.46	0.06
ADFI, lb	7.02	7.13	6.85	6.91	7.12	7.11	6.84	6.69	7.01	7.04	6.98	6.58	0.15
F/G	3.29	3.26	3.01	3.09	3.00	2.76	2.75	2.78	2.83	2.74	2.74	2.70	0.07

	Lysine Linear Contrast, P<			Lysine Quadratic Contrast, P<			Paylean	
	0	4.5	9	0	4.5	9	Linear	Quadratic
Day 0 to 14								
ADG**	0.05	0.33	0.019	0.04	0.001	0.007	0.0001	0.003
ADFI	0.24	0.001	0.016	0.73	0.85	0.85	0.09	0.89
F/G**	0.0001	0.0001	0.0001	0.006	0.001	0.007	0.0001	0.0001
Day 0 to 28								
ADG	0.09	0.83	0.72	0.47	0.03	0.07	0.001	0.003
ADFI	0.39	0.02	0.05	0.85	0.66	0.15	0.51	0.99
F/G	0.006	0.03	0.20	0.43	0.04	0.72	0.0001	0.001

[a]A total of 432 pigs with an average initial weight of 175 lb was used in this experiment. Values represent the mean of 12 pens/treatment with 3 (d 0 to 14) and 2 (d 14 to 28) pigs per pen.
*Sex by trial interaction (P<0.05).
**Trial by treatment interaction (P<0.05).
***Sex by treatment interaction (P<0.05).

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Table 3. Effect of Dietary Lysine and Paylean on Carcass Characteristics, Day 14[a]

Paylean, g/ton:	0.0				4.5				9.0				
Lysine, %:	0.6	0.8	1.0	1.2	0.8	1.0	1.2	1.4	0.8	1.0	1.2	1.4	SEM
Live wt, lb	205.0	202.7	207.2	208.4	204.6	205.3	212.8	207.2	212.8	206.9	214.1	209.0	3.63
Yield, %	72.6	72.9	73.0	72.8	73.5	73.1	73.6	73.8	73.4	73.9	72.9	73.2	0.41
Hot carcass wt, lb	148.3	147.2	150.9	151.5	150.2	149.5	156.7	152.9	156.5	152.9	156.4	153.2	2.76
Cold carcass wt, lb	147.0	146.4	149.6	150.4	149.2	148.5	155.7	151.6	155.0	151.6	156.3	151.6	2.81
Carcass length, in	31.4	31.1	31.4	31.4	31.5	31.6	31.2	31.1	31.1	31.4	31.2	30.9	0.21
Leaf fat, lb	2.12	1.89	1.76	1.81	1.71	2.16	1.62	1.47	1.78	1.61	1.25	1.58	0.19
Backfat thickness, in													
First rib	1.54	1.56	1.27	1.43	1.43	1.56	1.36	1.45	1.41	1.44	1.31	1.33	0.07
Last rib	0.82	0.78	0.78	0.78	0.79	0.76	0.84	0.80	0.78	0.80	0.73	0.71	0.03
Last lumbar	0.60	0.56	0.51	0.52	0.52	0.55	0.52	0.50	0.55	0.52	0.45	0.46	0.03
Average backfat	0.98	0.97	0.85	0.91	0.91	0.96	0.91	0.92	0.91	0.92	0.83	0.83	0.03
Tenth rib	0.62	0.70	0.61	0.65	0.67	0.62	0.57	0.55	0.62	0.62	0.64	0.59	0.06
Percentage lean	55.1	54.2	55.8	54.8	54.5	54.4	56.2	56.3	55.7	55.8	56.4	56.5	0.89
Loin eye area, in^2	5.61	5.69	5.82	5.65	5.59	5.70	5.91	5.75	5.86	5.94	6.28	5.97	0.19

	Lysine Linear Contrast, P<			Lysine Quadratic Contrast, P<			Paylean	
	0	4.5	9	0	4.5	9	Linear	Quadratic
Live wt*	0.37	0.36	0.79	0.63	0.41	0.91	0.06	0.70
Yield	0.63	0.46	0.42	0.50	0.47	0.85	0.08	0.09
Hot carcass wt*	0.29	0.23	0.60	0.78	0.54	0.95	0.01	0.85
Cold carcass wt*	0.28	0.25	0.67	0.82	0.54	0.81	0.01	0.87
Carcass length	0.76	0.15	0.34	0.42	0.54	0.17	0.32	0.39
Leaf fat	0.22	0.14	0.25	0.46	0.11	0.19	0.02	0.91
Backfat Thickness								
First rib	0.05	0.66	0.20	0.29	0.82	0.96	0.12	0.30
Last rib*	0.49	0.43	0.07	0.57	0.76	0.56	0.16	0.25
Last lumbar	0.04	0.45	0.01	0.43	0.38	0.51	0.02	0.82
Average backfat**	0.03	0.79	0.03	0.26	0.60	0.98	0.03	0.26
Tenth rib*	0.92	0.10	0.76	0.68	0.80	0.62	0.44	0.44
Percentage lean	0.89	0.13	0.44	0.94	0.63	0.98	0.10	0.92
Loin eye area	0.75	0.44	0.44	0.52	0.50	0.33	0.03	0.33

[a]A total of 432 pigs with an average initial weight of 175 lb was used in this experiment. Values represent the mean of 12 pens/treatment with 3 (d 0 to 14) and 2 (d 14 to 28) pigs per pen. *Sex by trial interaction (P<0.05). **Trial by treatment interaction (P<0.05). ***Sex by treatment interaction (P<0.05).

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Table 4. Effect of Dietary Lysine and Paylean on Carcass Characteristics, Day 28[a]

Paylean, g/ton:	0.0				4.5				9.0				
Lysine, %:	0.6	0.8	1.0	1.2	0.8	1.0	1.2	1.4	0.8	1.0	1.2	1.4	SEM
Live wt, lb	230.3	232.9	225.8	233.7	236.8	246.3	239.9	234.6	240.3	240.2	242.7	238.1	3.58
Yield, %	73.7	73.7	73.9	73.3	74.1	74.6	74.2	74.1	74.8	75.8	74.6	74.6	0.38
Hot carcass wt, lb	169.0	171.1	166.0	170.7	175.4	184.7	178.3	173.7	180.1	182.5	181.7	177.8	2.81
Cold carcass wt, lb	166.7	168.8	163.7	168.4	173.3	182.5	176.0	171.5	178.3	179.9	179.2	175.5	2.78
Carcass length, in	32.3	32.3	32.2	32.5	32.2	32.1	32.1	33.2	32.0	32.4	32.5	31.6	0.43
Leaf fat, lb	2.65	2.64	2.48	2.60	2.51	2.09	1.95	1.90	2.17	1.94	1.72	1.86	0.15
Backfat thickness, in													
First rib	1.46	1.46	1.48	1.44	1.47	1.43	1.36	1.36	1.43	1.40	1.32	1.28	0.05
Last rib	0.91	0.89	0.89	0.88	0.92	0.86	0.88	0.82	0.91	0.86	0.86	0.86	0.03
Last lumbar	0.63	0.65	0.64	0.61	0.58	0.59	0.53	0.49	0.54	0.52	0.50	0.49	0.03
Average backfat	1.00	1.00	1.00	0.98	0.99	0.96	0.92	0.89	0.96	0.93	0.89	0.88	0.03
Tenth rib	0.80	0.74	0.76	0.77	0.77	0.74	0.71	0.59	0.66	0.68	0.63	0.65	0.04
Percentage lean	51.9	53.2	52.9	53.5	53.5	54.7	54.7	54.9	55.1	55.0	55.2	55.2	0.73
Loin eye area, in^2	5.83	5.99	5.93	6.24	6.31	6.69	6.54	6.09	6.48	6.51	6.35	6.49	0.21

	Lysine Linear Contrast, P<			Lysine Quadratic Contrast, P<			Paylean	
	0	4.5	9	0	4.5	9	Linear	Quadratic
Live wt*	0.85	0.42	0.80	0.47	0.04	0.53	0.0003	0.08
Yield	0.59	0.92	0.29	0.37	0.46	0.19	0.0001	0.83
Hot carcass wt*	0.99	0.37	0.55	0.65	0.02	0.27	0.0001	0.07
Cold carcass wt*	0.99	0.33	0.47	0.63	0.01	0.34	0.0001	0.06
Carcass length	0.88	0.11	0.59	0.72	0.19	0.16	0.56	0.50
Leaf fat	0.65	0.01	0.10	0.67	0.24	0.23	0.0001	0.14
Backfat Thickness								
First rib	0.90	0.09	0.02	0.70	0.69	0.89	0.01	0.84
Last rib*	0.51	0.04	0.21	0.87	0.91	0.37	0.42	0.46
Last lumbar	0.60	0.02	0.17	0.38	0.41	0.90	0.0001	0.20
Average backfat**	0.63	0.01	0.03	0.64	0.98	0.79	0.002	0.42
Tenth rib*	0.61	0.003	0.64	0.39	0.29	0.97	0.001	0.74
Percentage lean	0.18	0.20	0.87	0.62	0.54	0.94	0.0002	0.29
Loin eye area	0.20	0.37	0.87	0.72	0.05	0.79	0.01	0.15

[a]A total of 432 pigs with an average initial weight of 175 lb was used in this experiment. Values represent the mean of 12 pens/treatment with 3 (d 0 to 14) and 2 (d 14 to 28) pigs per pen. *Sex by trial interaction (P<0.05). **Trial by treatment interaction (P<0.05). ***Sex by treatment interaction (P<0.05).

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Table 5. Effect of Dietary Lysine and Paylean on Chemical Composition and Tissue Accretion[a]

Paylean, g/ton:	0.0				4.5				9.0				
Lysine, %:	0.6	0.8	1.0	1.2	0.8	1.0	1.2	1.4	0.8	1.0	1.2	1.4	SEM
Day 14, Chemical Composition, %													
Moisture	58.2	59.2	60.2	59.5	60.1	59.5	60.1	60.4	59.5	59.7	61.0	61.4	0.62
Fat	20.6	19.5	18.1	18.0	18.0	18.9	17.8	18.1	18.9	18.6	17.0	17.0	0.84
Protein	17.3	17.7	17.7	17.9	17.8	17.7	18.2	17.9	17.9	17.8	18.2	18.0	0.22
Ash	3.22	3.33	3.13	3.26	3.32	3.21	3.24	3.21	2.88	3.23	3.18	3.17	0.14
Day 28, Chemical Composition, %													
Moisture	56.9	57.3	57.5	57.7	57.8	58.3	59.8	60.7	59.0	58.8	60.1	60.6	0.59
Fat	22.0	21.3	21.2	20.3	21.3	20.3	18.4	17.4	19.2	19.8	17.7	17.4	0.80
Protein	17.1	17.2	17.6	17.6	17.4	17.7	18.2	18.2	18.1	18.0	18.4	18.3	0.26
Ash	3.28	3.33	3.14	3.14	3.00	3.12	3.00	3.10	3.03	3.11	3.11	3.10	0.14
Day 0 to 14, Tissue Accretion, g/d													
Moisture	269	404	497	400	457	429	555	500	501	526	604	608	51
Fat	249	225	176	182	168	213	179	171	227	215	143	151	52
Protein	122	170	181	173	181	174	224	191	205	205	227	215	16
Ash	38	46	39	43	46	42	47	42	33	46	44	44	9
Day 0 to 28, Tissue Accretion, g/d													
Moisture	379	389	401	398	461	543	541	539	535	546	563	562	25
Fat	216	195	191	171	212	213	141	111	168	194	125	114	26
Protein	133	136	145	151	159	187	189	182	191	191	199	188	10
Ash	33	34	30	30	28	35	29	31	31	34	33	32	4

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Table 5. Continued

	Lysine linear contrast, P<			Lysine quadratic contrast, P<			Paylean	
	0	4.5	9	0	4.5	9	Linear	Quadratic
Day 14, Chemical Composition, %								
Moisture**	0.09	0.53	0.02	0.18	0.49	0.83	0.02	0.66
Fat*	0.06	0.81	0.06	0.31	0.70	0.90	0.03	0.54
Protein*	0.07	0.46	0.57	0.56	0.82	0.76	0.03	0.42
Ash	0.92	0.60	0.21	0.96	0.76	0.20	0.21	0.41
Day 28, Chemical Composition, %								
Moisture*	0.33	0.0002	0.02	0.82	0.73	0.58	0.0001	0.07
Fat	0.16	0.0003	0.03	0.92	0.96	0.58	0.0001	0.31
Protein	0.08	0.01	0.39	0.79	0.57	0.97	0.0001	0.46
Ash	0.32	0.77	0.73	0.86	0.93	0.75	0.16	0.22
Day 0 to 14, Tissue Accretion, g/d								
Moisture**	0.01	0.17	0.04	0.01	0.74	0.81	0.0001	0.72
Fat*	0.19	0.89	0.14	0.73	0.52	0.82	0.45	0.61
Protein*	0.006	0.16	0.41	0.04	0.32	0.62	0.0001	0.52
Ash	0.73	0.83	0.46	0.70	0.99	0.44	0.77	0.56
Day 0 to 28, Tissue Accretion, g/d								
Moisture*	0.51	0.02	0.32	0.79	0.07	0.79	0.0001	0.001
Fat	0.19	0.001	0.03	0.99	0.49	0.44	0.01	0.86
Protein	0.09	0.07	0.97	0.88	0.03	0.51	0.0001	0.02
Ash	0.39	0.86	0.92	0.77	0.47	0.58	0.69	0.51

[a]A total of 432 pigs with an average initial weight of 175 lb was used in this experiment. Values represent the mean of 12 pens/treatment with 3 (d 0 to 14) and 2 (d 14 to 28) pigs per pen.
*Sex by trial interaction (P<0.05).
**Trial by treatment interaction (P<0.05).
***Sex by treatment interaction (P<0.05).

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INTERACTIVE EFFECTS BETWEEN PAYLEAN™ (RACTOPAMINE HCL) AND DIETARY LYSINE ON PORK QUALITY, LOIN, BELLY, AND HAM COMPOSITION [1]

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Summary

A total of 432 pigs were used to evaluate the effects of Paylean and dietary lysine on pork quality and loin, belly, and ham composition. The 12 dietary treatments included Paylean (0, 4.5, and 9.0 g/ton) and 4 levels of lysine. For pigs fed no Paylean, lysine levels were 0.60, 0.80, 1.00, and 1.20%. For pigs fed 4.5 or 9.0 g/ton of Paylean, lysine levels were 0.80, 1.00, 1.20, and 1.40%. The results indicate that pigs fed Paylean and increasing levels of lysine will have less loin marbling and belly firmness compared to control pigs fed lower levels of lysine.

(Key Words: Paylean, Lysine, Finishing Pigs, Pork Quality.)

Introduction

Paylean has been shown to increase protein and decrease fat accretion resulting in a faster growing, leaner pig. Also, adding lysine to the diet can have the same effects on protein and fat accretion. However, this effect could lead to undesirable pork quality and could alter composition in the loin, belly, and ham. The objectives of this experiment were to evaluate the interactive effects of dietary lysine and Paylean dosage on pork quality and loin, belly, and ham composition.

Procedures

Four hundred thirty-two pigs (PIC 326 × C22) averaging 175 lb were used in this experiment. The experiment was divided into two identical trials, the first beginning in October 2000, and the second starting in February 2001. The procedures used were identical for the two trials. Pigs were housed with three per pen and 12 pens (1.5 × 1.5 m) per treatment (six pens of barrows and six pens of gilts) in a randomized complete block design. Pigs were blocked by initial weight and sex, then randomly allotted to one of the 12 experimental treatments. Feed and water were provided ad libitum.

The experiment was arranged in an incomplete 3 × 4 factorial. Main effects included Paylean dosage (0, 4.5 and 9 g/ton) and dietary lysine. For control pigs, diets contained 0.60, 0.80, 1.00, and 1.20% total lysine and for pigs fed Paylean, diets contained 0.80, 1.00, 1.20, and 1.40% total lysine. Details on diet composition are provided in the previous report on page 77. The dietary treatments were fed from 175 to 240 lb.

At the beginning of the trial, pigs were randomly assigned either to a midpoint slaughter (d 14), ending slaughter (d 28) or as an alternate in case a pig was removed due

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[2]Food Animal Health and Management Center.

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to death, sickness, or being 2 standard deviations from treatment mean. One pig per pen was processed at the KSU Meat Lab on d 14 (midpoint) and 28 (end) of the trial. At 24 h postmortem, carcasses were fabricated into the primal cuts for further data collection. Following a 30 minute bloom, the loin surface at the 10th rib was analyzed for color (Hunter L*a*b* values), drip loss, ultimate pH, visual color, firmness and marbling.

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 ranged from 1 to 5 with 1 representing very soft and watery lean and 5 representing very firm and dry lean. After visual scores, 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, wavelength, 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 b* value, the more yellow the sample is in color. The a:b ratio indicates a change in redness. The higher the ratio, the darker red 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 wavelength is a ratio between the wavelength values of 630 and 580. It represents a ratio of reflectance or the amount of oxymyoglobin present. The higher the ratio, the more oxymyoglobin present.

After evaluating color, the chops were dissected and a 1-cu in. sample was taken to determine drip loss. 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.

After spareribs were removed and the belly trimmed, belly firmness was evaluated by suspending the belly perpendicularly over a bar (skin side up) and the distance was recorded between the belly ends initially and after a five-minute period. Higher values represent firmer bellies. A sample from each loin (9th rib), ham (biceps femoris), and belly, from the same anatomical region on every pig, was collected, frozen, and later analyzed for protein, lipid, and moisture content for the measurement of tissue composition. Data were analyzed using the GLM procedure of SAS.

Results

Pork Quality. For the midpoint pork quality data (Table 1), there was a significant trial x treatment interaction for L* values. For the L* interaction, increasing dietary lysine decreased L* values in control pigs in trial 2, but not in trial 1.

As Paylean dosage increased, loin visual color score (quadratic, $P<0.01$) and a* and b* values (linear, $P<0.01$) decreased Furthermore, saturation index decreased linearly as Paylean dosage increased ($P<0.001$). In pigs fed 4.5 g/ton of Paylean, drip loss percentage decreased (quadratic, $P<0.02$) and loin temperature increased (linear, $P<0.02$) as dietary lysine increased. In control pigs (no Paylean), increasing dietary lysine decreased L* values (linear, $P<0.01$) and b* values and saturation index (quadratic, $P<0.03$), but increased wavelength (linear, $P<0.02$).

For the endpoint pork quality data (d-28, Table 2), increasing Paylean decreased (linear, $P<0.0001$) initial and 5-minute belly firmness. In addition, for pigs fed 4.5 g/ton of Paylean both belly firmness measurements decreased (linear, $P<0.01$ and quadratic, $P<0.04$) as dietary lysine increased. Pigs fed 9.0 g/ton of Paylean had an increase (quadratic, $P<0.04$) in drip loss percentage and

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decrease (quadratic, P<0.05) in visual firmness score as dietary lysine increased. In pigs fed Paylean, visual marbling score, decreased (linear P<0.05) as lysine increased.

Chemical Composition. Several trial x treatment interactions were observed for chemical composition (d-14, Table 3) including percentages of loin moisture, belly moisture, belly fat, and belly crude protein. These interactions all have one or more treatments in one trial that did not appear to have the same response as the same treatment in the other trial. However, despite these interactions, the general trends for these responses are the same. In addition, any trial × sex interactions were due to the difference in magnitude in response between genders when comparing the trials.

Increasing Paylean increased (linear P<0.05) loin percentage crude protein and decreased (linear P<0.007) percentage crude fat. In control pigs, increasing dietary lysine increased (linear, P<0.05) loin moisture percentage. In pigs fed 9.0 g/ton of Paylean, loin fat percentage decreased (quadratic, P<0.005) as dietary lysine increased. In pigs fed 4.5 g/ton of Paylean, loin crude protein percentage increased (quadratic, P<0.03) as dietary lysine increased.

In pigs fed 0 and 9.0 g/ton of Paylean, ham fat percentage decreased (linear, P<0.03) as dietary lysine increased. Increasing Paylean increased belly moisture percentage (linear, P<0.03). In control pigs, belly moisture increased (linear, P<0.03) and fat percentage decreased (linear, P<0.05) as dietary lysine increased. Furthermore, pigs fed either 0 or 9.0 g/ton of Paylean had increased (linear, P<0.0008 and P<0.05, respectively) belly crude protein percentage as dietary lysine increased.

Similar to the midpoint composition, there were several interactions observed for loin, ham, and belly composition in pigs slaughtered after 28 days on test (Table 5). These interactions included a trial by treatment interaction for loin moisture percentage and a sex by treatment interaction for loin fat percentage. For the loin moisture percentage interaction, several treatments responded differently between the two trials. Although the treatments responded differently, loin moisture percentages for the two trials were in a narrow range of 73.8 to 74.2%. The loin fat percentage interaction appears to be due to the gilts fed .80% lysine and 4.5 g/ton of Paylean having a higher percentage of loin fat than barrows from that treatment.

As Paylean dosage increased, loin fat and ham ash percentage decreased (linear, P<0.04) and loin crude protein percentage increased (linear, P<0.01). In addition, as Paylean dosage increased, belly moisture, crude protein, and ash percentage increased (linear, P<0.05) and belly fat percentage decreased (linear, P<0.001). For loin composition of pigs fed 4.5 g/ton of Paylean, moisture percentage increased (linear, P<0.05) as dietary lysine increased. In addition, loin fat percentage decreased as lysine increased for pigs fed 0, 4.5 and 9.0 g/ton of Paylean (linear, P<0.05, .006, and .03, respectively). In pigs fed 9.0 g/ton of Paylean, loin crude protein percentage increased (linear, P<0.02) as dietary lysine increased. As Paylean increased, ham fat percentage decreased (linear, P<0.003), and for pigs fed either 0 or 9.0 g/ton of Paylean, increasing dietary lysine decreased (linear, P<0.04) ham fat percentage. In addition, ham crude protein percentage increased (linear, P<0.05) as lysine increased in pigs fed 9.0 g/ton of Paylean. In pigs fed 4.5 g/ton of Paylean, belly moisture percentage and ash percentage increased (linear, P<0.02 and 0.01, respectively), but fat percentage decreased (linear, P<0.02) as lysine increased. At 9.0 g/ton of Paylean, there was an increase in moisture (linear, P<0.007) and crude protein percentage (linear, P< .005) but a decrease in fat percentage (linear, P<0.001) as lysine increased.

Discussion

At the end of the trial, increasing either Paylean or dietary lysine had no effect on drip loss percentage, pH, temperature, loin color or firmness. However, increasing either Paylean or dietary lysine decreased marbling score and belly firmness. Loin composition agreed with the decrease in

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marbling score, with pigs fed Paylean having decreased loin fat percentage and increased loin crude protein percentage. The changes in belly firmness appear to be correlated with changes in chemical composition. In pigs fed Paylean, belly fat percentage decreased and belly crude protein percentage increased. In addition, increasing dietary lysine linearly decreased loin, ham, and belly fat percentage in both Paylean and non-Paylean fed pigs. Although both control and Paylean fed pigs responded to increasing dietary lysine, control pigs generally had the greatest improvement as lysine increased from .6 to .8%, whereas Paylean fed pigs appeared to respond to the higher lysine levels of 1.0 to 1.2%.

From previous studies, we know Paylean increases growth performance by increasing lean gain and decreasing fat accretion. This results in a faster gaining, leaner pig. However, loin marbling and belly firmness appear to decrease as fat accretion decreases with the addition of lysine and Paylean. Pigs require higher dietary lysine when fed Paylean, however the higher dietary lysine will cause deterioration in marbling, but will result in a leaner product.

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Table 1. Effects of Dietary Lysine and Paylean on Loin and Belly Quality, Day 14[a]

Paylean, g/ton:	0.0				4.5				9.0				
Lysine, %:	0.6	0.8	1.0	1.2	0.8	1.0	1.2	1.4	0.8	1.0	1.2	1.4	SEM
Drip loss, %	3.47	3.99	3.73	2.93	4.14	2.70	3.68	4.72	3.77	3.68	3.42	2.94	0.51
Loin pH	5.54	5.51	5.52	5.54	5.51	5.53	5.51	5.53	5.49	5.53	5.55	5.52	0.02
Loin temp, °C	0.63	0.58	0.64	0.86	0.49	0.72	1.20	1.00	0.78	0.93	0.58	0.86	0.19
Color[b]	3.13	2.09	3.01	3.04	2.90	2.25	2.54	2.68	2.91	2.76	2.72	2.68	0.19
Firmness[c]	2.84	3.08	2.77	3.26	2.77	2.58	2.71	2.54	2.90	2.64	2.71	2.77	0.25
Marbling[d]	1.61	1.55	1.56	1.54	1.68	1.45	1.70	1.17	1.86	1.39	1.51	1.44	0.17
L*	62.1	60.8	59.2	59.5	60.5	58.5	61.1	59.6	59.1	60.6	59.7	10.3	0.72
a*	7.94	7.49	7.76	8.23	7.47	7.79	7.64	7.72	7.32	7.39	7.14	7.35	0.28
b*	16.2	15.7	15.3	16.3	15.2	15.5	15.8	15.4	14.8	15.3	14.9	15.3	0.33
Wavelength	2.33	2.31	2.38	2.45	2.29	2.40	2.31	2.37	2.33	2.29	2.34	2.31	0.04
Hue angle	64.0	64.5	63.1	63.2	63.8	63.3	64.2	63.4	63.8	64.2	64.5	64.3	0.68
Saturation index	18.0	17.4	17.2	18.3	16.9	17.3	17.5	17.2	16.5	17.0	16.5	17.0	0.39
a*:b*	0.49	0.48	0.51	0.51	0.49	0.50	0.48	0.50	0.49	0.48	0.48	0.48	0.01
Initial belly flop, in	6.51	6.02	5.23	6.07	6.24	5.55	6.06	5.01	5.35	5.72	4.33	5.59	0.58
5 min belly flop, in	5.77	5.37	4.65	5.28	5.55	4.99	5.52	4.39	4.77	5.10	3.71	5.07	0.51

[a]A total of 432 pigs with an average initial weight of 175 lb was used in this experiment. Values represent the mean of 12 pens/treatment with one pig/pen.
[b]Scoring system of 1 to 5: 2 = grayish pink; 3 = reddish pink; and 4 = purplish red.
[c]Scoring system of 1 to 5: 2 = soft and exudative; 3 = slightly firm and moist; and 4 = firm and moderately dry.
[d]Scoring system of 1 to 5: 2 = traces to slight; 3 = small to modest; and 4 = moderate to slightly abundant.

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Table 1. Continued

	Lysine Linear Contrast P<			Lysine Quadratic Contrast P<			Paylean Response	
	0	4.5	9	0	4.5	9	Linear	Quadratic
Drip loss	0.41	0.23	0.22	0.20	0.02	0.69	0.84	0.30
Loin pH	0.95	0.82	0.30	0.22	0.94	0.10	0.53	0.86
Loin temp[e]	0.37	0.02	0.89	0.48	0.27	0.72	0.44	0.30
Color	0.68	0.66	0.38	0.87	0.03	0.77	0.03	0.01
Firmness	0.40	0.63	0.78	0.63	0.97	0.53	0.22	0.15
Marbling	0.78	0.10	0.13	0.89	0.38	0.25	0.92	0.57
L*	0.01	0.96	0.45	0.28	0.76	0.51	0.37	0.54
a*	0.38	0.64	0.90	0.11	0.68	0.81	0.01	0.66
b*	0.97	0.53	0.47	0.03	0.31	0.90	0.002	0.85
Wavelength	0.02	0.40	0.88	0.22	0.52	0.91	0.09	0.94
Hue angle	0.23	0.91	0.54	0.73	0.87	0.63	0.34	0.51
Saturation index	0.78	0.54	0.60	0.03	0.37	0.98	0.001	0.99
a*:b*	0.22	0.94	0.59	0.74	0.80	0.57	0.37	0.53
Initial belly flop	0.46	0.22	0.80	0.26	0.75	0.45	0.10	0.75
5 min belly flop	0.38	0.19	0.83	0.32	0.57	0.32	0.11	0.63

[E]Sex by trial interaction (P<0.05).

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Table 2. Effects of Dietary Lysine and Paylean on Loin and Belly Quality, Day 28[a]

Paylean, g/ton:	0.0				4.5				9.0				
Lysine, %:	0.6	0.8	1.0	1.2	0.8	1.0	1.2	1.4	0.8	1.0	1.2	1.4	SEM
Drip loss, %	4.11	3.28	3.13	3.85	3.16	3.52	4.11	3.57	3.46	4.22	4.00	2.95	0.44
Loin pH	5.53	5.57	5.59	5.59	5.62	5.50	5.60	5.57	5.60	5.75	5.49	5.61	0.07
Loin temp, °C	0.35	0.54	0.44	0.36	0.52	0.32	0.42	0.44	0.32	0.40	0.52	0.34	0.10
Color[b]	2.85	2.83	2.70	2.95	2.87	3.13	2.90	2.77	2.62	2.73	2.68	2.81	0.17
Firmness[c]	3.20	3.14	2.92	3.48	3.00	3.46	2.95	2.76	3.23	2.97	2.64	3.28	0.23
Marbling[d]	1.71	1.63	1.34	1.50	1.58	1.45	1.37	1.13	1.83	1.58	1.29	1.50	0.14
L*	59.8	60.6	59.4	59.4	60.2	61.4	60.3	60.5	60.0	60.3	60.3	60.8	0.92
a*	8.19	7.96	8.15	7.91	7.72	7.84	7.46	7.93	8.19	7.99	8.39	7.97	0.36
b*	16.1	15.9	15.7	15.8	15.4	16.0	15.8	16.4	16.3	15.8	16.4	16.0	0.40
Wavelength	2.41	2.37	2.41	2.41	2.34	2.34	2.32	2.37	2.44	2.39	2.44	2.35	0.06
Hue angle	63.1	63.5	62.6	63.6	63.5	63.9	64.7	64.2	63.6	63.2	62.9	63.5	0.91
Saturation index	18.1	17.8	17.7	17.8	17.3	17.8	17.4	18.3	18.3	17.8	18.5	17.9	0.47
a*:b*	0.51	0.50	0.52	0.50	0.50	0.49	0.47	0.49	0.50	0.51	0.52	0.50	0.02
Initial belly flop, in	9.15	7.96	8.53	8.15	8.59	6.73	5.61	6.61	6.41	7.10	5.81	5.86	0.62
5 min belly flop, in	7.92	7.40	7.71	7.24	7.72	6.06	5.03	5.91	5.63	6.44	5.11	5.11	0.57

[a]A total of 432 pigs with an average initial weight of 175 lb was used in this experiment. Values represent the mean of 12 pens/treatment with one pig/pen.
[b]Scoring system of 1 to 5: 2 = grayish pink; 3 = reddish pink; and 4 = purplish red.
[c]Scoring system of 1 to 5: 2 = soft and exudative; 3 = slightly firm and moist; and 4 = firm and moderately dry.
[d]Scoring system of 1 to 5: 2 = traces to slight; 3 = small to modest; and 4 = moderate to slightly abundant.

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Table 2. Continued

	Lysine Linear Contrast P<			Lysine Quadratic Contrast P<			Paylean Response	
	0	4.5	9	0	4.5	9	Linear	Quadratic
Drip loss	0.63	0.35	0.37	0.08	0.32	0.04	0.86	0.90
Loin pH	0.50	0.85	0.48	0.78	0.53	0.84	0.47	0.68
Loin temp[e]	0.89	0.76	0.67	0.14	0.24	0.18	0.72	0.80
Color	0.83	0.49	0.50	0.42	0.28	0.95	0.39	0.17
Firmness	0.54	0.23	0.86	0.18	0.17	0.05	0.42	0.65
Marbling	0.15	0.03	0.05	0.38	0.68	0.11	0.96	0.07
L*	0.54	0.95	0.55	0.65	0.59	0.93	0.51	0.33
a*	0.68	0.88	0.87	0.99	0.64	0.76	0.77	0.11
b*	0.58	0.12	0.76	0.68	0.91	0.90	0.45	0.63
Wavelength	0.88	0.75	0.34	0.76	0.63	0.76	0.89	0.10
Hue angle	0.88	0.50	0.97	0.75	0.61	0.55	0.87	0.15
Saturation index	0.58	0.20	0.73	0.72	0.79	0.99	0.48	0.32
a*:b*	0.91	0.49	0.97	0.84	0.60	0.56	0.83	0.12
Initial belly flop	0.37	0.01	0.29	0.51	0.03	0.61	0.0001	0.02
5 min belly flop	0.48	0.01	0.24	0.96	0.04	0.47	0.0001	0.26

[e]Sex by trial interaction (P<0.05).

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Table 3. Effects of Dietary Lysine and Paylean on Chemical Composition of the Loin, Ham and Belly, Day 14[a]

Paylean, g/ton:	0.0				4.5				9.0				
Lysine, %:	0.6	0.8	1.0	1.2	0.8	1.0	1.2	1.4	0.8	1.0	1.2	1.4	SEM
Loin, %[b]													
Moisture	74.1	74.4	75.1	74.6	74.3	74.0	74.3	74.7	74.1	74.4	74.7	74.4	0.24
Fat	1.98	1.85	1.57	1.68	2.21	2.38	1.42	1.44	2.53	1.94	1.55	1.80	0.21
Crude protein	21.5	21.4	21.3	21.6	21.1	22.0	22.4	21.9	21.3	21.0	22.0	22.3	0.32
Ash	1.55	1.57	1.58	1.64	1.50	1.55	1.56	1.42	1.47	1.57	1.53	1.42	0.07
Ham, %[c]													
Moisture	75.0	74.8	74.9	74.9	75.0	74.8	74.7	74.8	74.9	75.0	75.2	74.7	0.20
Fat	1.25	1.03	0.88	0.96	1.07	1.05	0.94	1.10	1.27	1.18	0.85	0.05	0.10
Crude protein	21.8	22.2	22.0	22.1	21.7	22.5	22.2	22.4	21.8	21.7	22.3	22.3	0.28
Ash	1.76	1.78	1.75	1.74	1.73	1.71	1.81	1.78	1.84	1.78	1.67	1.67	0.07
Belly, %[d]													
Moisture	48.9	50.2	52.7	52.7	52.0	51.3	54.6	53.3	51.8	52.3	54.2	53.3	1.12
Fat	35.7	33.6	30.0	29.8	31.8	31.7	27.8	29.6	32.0	30.9	28.3	29.7	1.52
Crude protein	13.9	14.7	15.7	16.0	15.1	15.7	16.5	15.7	15.0	15.5	15.9	16.2	0.43
Ash	0.67	0.73	0.76	0.75	0.79	0.78	0.81	0.79	0.74	0.78	0.78	0.81	0.04

[a]A total of 432 pigs with an average initial weight of 175 lb was used in this experiment. Values represent the mean of 12 pens/treatment with one pig/pen.
[b]The loin sample taken was from the lean tissue of the 9th chop.
[c]The ham sample taken was from the lean tissue of the biceps femoris.
[d]The belly sample was a center slice (skin, fat, and lean) from the belly.

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Table 3. Continued

	Lysine Linear Contrast P<			Lysine Quadratic Contrast P<			Paylean Response	
	0	4.5	9	0	4.5	9	Linear	Quadratic
Loin								
Moisture[e]	0.05	0.21	0.24	0.13	0.13	0.31	0.34	0.21
Fat[f]	0.25	0.001	0.007	0.58	0.73	0.05	0.23	0.99
Crude protein	0.88	0.05	0.006	0.63	0.03	0.26	0.33	0.12
Ash	0.43	0.43	0.53	0.83	0.18	0.14	0.10	0.47
Ham								
Moisture	0.85	0.40	0.73	0.57	0.48	0.13	0.72	0.41
Fat[f]	0.03	0.98	0.001	0.12	0.40	0.77	0.83	0.99
Crude protein	0.45	0.10	0.10	0.60	0.24	0.85	0.92	0.30
Ash	0.75	0.44	0.11	0.77	0.94	0.53	0.66	0.72
Belly								
Moisture[e]	0.01	0.16	0.19	0.57	0.77	0.53	0.03	0.25
Fat[f]	0.005	0.13	0.17	0.56	0.52	0.44	0.07	0.29
Crude protein[f]	0.0008	0.17	0.05	0.59	0.10	0.90	0.08	0.16
Ash	0.13	0.97	0.18	0.35	0.94	0.85	0.07	0.10

[e]Trial by treatment interaction (P<0.05).
[f]Sex by trial interaction (P<0.05).

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Table 4. Effects of Dietary Lysine and Paylean on Chemical Composition of the Loin, Ham and Belly, Day 28[a]

Paylean, g/ton:	0.0				4.5				9.0				
Lysine, %:	0.6	0.8	1.0	1.2	0.8	1.0	1.2	1.4	0.8	1.0	1.2	1.4	SEM
Loin, %[b]													
Moisture	73.8	73.8	74.0	73.8	73.8	74.1	74.3	74.4	73.8	74.0	74.2	74.2	0.22
Fat	2.49	2.04	1.78	1.96	2.23	1.78	1.43	1.51	2.25	1.65	1.50	1.66	0.20
Crude protein	21.4	21.9	22.0	22.1	2.18	22.1	22.6	22.0	21.7	22.4	22.5	22.7	0.27
Ash	1.59	1.60	1.54	1.47	1.44	1.45	1.47	1.45	1.47	1.55	1.41	1.48	0.06
Ham, %[c]													
Moisture	74.5	74.3	74.6	74.4	74.7	74.6	74.8	74.8	74.5	74.6	74.8	74.8	0.19
Fat	1.36	1.22	0.94	0.96	0.06	1.11	0.84	0.83	1.20	0.78	0.87	0.85	0.10
Crude protein	22.0	22.4	22.1	22.4	22.4	22.4	22.5	22.1	22.1	22.5	22.7	22.9	0.28
Ash	1.77	1.75	1.76	1.69	1.69	1.58	1.71	1.67	1.66	1.69	1.59	1.64	0.06
Belly, %[d]													
Moisture	48.2	49.2	48.8	49.5	49.5	49.0	51.7	52.2	50.3	50.4	52.4	53.8	1.01
Fat	36.1	34.3	35.6	34.4	34.7	35.4	31.6	30.9	33.8	33.6	30.4	28.8	1.40
Crude protein	14.4	15.1	14.3	14.7	15.3	14.9	15.6	15.6	14.8	15.0	16.3	16.2	0.39
Ash	0.65	0.71	0.69	0.73	0.71	0.70	0.74	0.81	0.72	0.76	0.73	0.77	0.03

[a]A total of 432 pigs with an average initial weight of 175 lb was used in this experiment. Values represent the mean of 12 pens/treatment with one pig/pen.
[b]The loin sample taken was from the lean tissue of the 9th chop.
[c]The ham sample taken was from the lean tissue of the biceps femoris.
[d]The belly sample was a center slice (skin, fat, and lean) from the belly.

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Table 4. Continued

	Lysine Linear Contrast P<			Lysine Quadratic Contrast P<			Paylean Response	
	0	4.5	9	0	4.5	9	Linear	Quadratic
Loin								
Moisture[e]	0.70	0.05	0.19	0.66	0.62	0.66	0.28	0.10
Fat[f]	0.05	0.006	0.03	0.12	0.19	0.06	0.04	0.15
Crude protein	0.10	0.37	0.02	0.43	0.09	0.32	0.01	0.64
Ash	0.10	0.76	0.68	0.44	0.78	0.93	0.07	0.06
Ham								
Moisture	0.98	0.69	0.23	0.89	0.76	0.94	0.12	0.14
Fat[f]	0.003	0.16	0.04	0.47	0.46	0.06	0.01	0.19
Crude protein	0.46	0.47	0.05	0.89	0.47	0.76	0.12	0.77
Ash	0.44	0.81	0.57	0.66	0.56	0.92	0.03	0.45
Belly								
Moisture[e]	0.46	0.02	0.007	0.90	0.63	0.50	0.0002	0.63
Fat[f]	0.57	0.02	0.005	0.85	0.62	0.60	0.001	0.78
Crude protein[f]	0.90	0.33	0.001	0.81	0.63	0.61	0.001	0.27
Ash	0.11	0.01	0.40	0.72	0.22	0.97	0.05	0.29

[e]Trial by treatment interaction (P<0.05).
[f]Sex by trial interaction (P<0.05).

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EFFECTS OF A DIRECT FED MICROBIAL (DMF-4) AND IN-FEED ANTIMICROBIALS ON PIG PERFORMANCE IN A COMMERCIAL FINISHING FACILITY [1]

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Summary

A total of 1,000 barrows were used in a 98-day trial conducted in a commercial research facility to determine the influence of a direct fed microbial with and without intermittent treatments of oxytetracycline (OTC) at 400 g/ton. The direct fed microbial was compared to a negative (no feed antimicrobial) and positive control (bacitracin methylene diasalicylate (BMD) at 30 g/ton, alternated with intermittent treatments of OTC at 400 g/ton). No significant differences between the four treatments were observed for any of the growth, efficiency, or carcass parameters evaluated. These results suggest that further work in quantifying the effects of routinely utilizing in-feed antimicrobials in the finishing period is warranted.

(Key Words: Microbial, Antimicrobial, Finishing Pigs.)

Introduction

Routine use of in-feed antimicrobials in animal agriculture is currently being debated as a public health issue. This concern is due to documented transmission of antimicrobial resistant food-borne bacteria transmitted to humans. Because reduced usage of antimicrobials is known to reduce selection pressure for antimicrobial resistance, reducing usage of in-feed antimicrobials should lead to lower amounts of resistant bacteria, and theoretically a lower incidence of antimicrobial resistant food-borne bacteria transmitted to humans. Therefore, there has been growing interest in identifying non-antimicrobial alternatives for growth promotion in swine. The direct fed microbial used in this study has shown promise for promoting growth in poultry. Direct fed microbials are hypothesized to positively impact the bacterial flora of the gastrointestinal tract by the ongoing inoculation with microbes being fed. Additionally, previous research has indicated a greater growth rate response of in-feed antimicrobials in commercial farms compared to university research facilities. Therefore, our objective was to evaluate the effects of the direct fed microbial to finishing pigs in a commercial research facility.

Procedures

This experiment was conducted in a commercial finishing research facility. Forty pens (10 pens/treatment) of barrows (PIC C22 × 337) were allotted to each treatment in a randomized complete block design with an average pig weight of 99.3 lb. Pens had totally slatted floors, were 10 × 18 ft, and contained 25 pigs per pen. Each pen was equipped with a dry feeder (Staco, 50 inches in length) and a cup waterer in this double curtain sided, deep-pitted finishing barn.

The four treatments consisted of a negative control, positive control, and feeding the direct fed microbial product with and with-

[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, Sam Hanni, and Robert Powell for technical assistance.

[2]Food Animal Health and Management Center.

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out intermittent treatments of OTC. The negative controls (NEG) were not fed any feed antimicrobials. The positive controls (POS) were fed BMD 30 g/ton alternated with 3, 1-week doses of OTC at 400 g/ton during weeks 1, 5, and 9 of the finishing period. The direct fed microbial (DFM) product was fed continuously without any antimicrobial pulses (DFM1) at a rate of 2 lb/ton during first two phases (8 weeks) of the feeding period, and at 1 lb/ton for the last two phases of the evaluation. The direct fed microbial product also was fed continuously in conjunction with 3, 1-week intermittent doses of 0TC at 400 g/ton (DFM2). These four dietary treatments were fed in four phases (Table 1). The diets fed were corn-soybean meal diets with 6% added fat, and 3 lb of synthetic lysine in all diets. Dietary energy, lysine, mineral, and vitamin content were identical for all diets within each phase. Diets were formulated to include 1.05%, 0.85%, 0.70%, and 0.60% total dietary lysine, 0.62%, 0.61%, 0.52%, and 0.51% calcium, and 0.58%, 0.56%, 0.47%, and 0.47% phosphorus for phases 1, 2, 3, and 4 respectively.

Pigs were weighed and pen weights were obtained every 14 days. Feed delivery was recorded daily for each pen, and feed remaining at the end of each phase was removed from the feeder and weighed. This enabled feed intake and feed efficiency to be determined for each pen.

On day 84 of the trial, the four biggest pigs were removed from each pen. The weight of these pigs was used to calculate the ADG, ADFI, and F/G for each pen. However, the carcass data from these pigs was not used in the carcass analysis. The remaining pigs were weighed off-test and sold on day 98 of the trial. All pigs in each pen were identified with a unique tattoo and maintained by pen integrity through the packing plant. Thus, mean carcass characteristics were calculated for each pen. At slaughter, fat and loin depth were measured with an optical probe to calculate percent lean. Fat, loin depth, and percent lean were adjusted to a common carcass weight for statistical evaluation. Data were analyzed using GLM procedures of SAS in a randomized complete block design.

Results and Discussion

There were no significant differences ($P>0.10$) between treatments for any of the growth, intake, efficiency, or carcass parameters measured (Table 2). Performance improvements were not observed in pigs fed the DFM or the antimicrobial regimens compared to pigs fed the negative control diets without an antimicrobial.

It should be noted that this barn of pigs was diagnosed with clinical salmonellosis during phase 2 (d 29 to 56) of the experiment. *Salmonella choleraesuis* was isolated from affected pigs at necropsy. The pigs were orally vaccinated and recovered. The reduction in growth during phase 2 of this trial associated with this disease episode is evident. It appears that neither the direct fed microbial nor the antimicrobials being fed influenced the outcome of this challenge.

Intensifying pressures to reduce or eliminate the use of in-feed antimicrobials as growth promoters will continue to drive the need for the development of non-antimicrobial growth promoters. However, the direct fed microbial product did not demonstrate any impact on the growth or carcass performance measured in this trial. This trial also would suggest that further work in quantifying the effects of routinely utilizing in-feed antimicrobials in the finishing period might be warranted.

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Table 1. Diet Feeding Regimen For Direct Fed Microbial Evaluation

	Treatment			
Item	Negative	Positive	DFM1	DFM2
Phase 1				
Day 0 to 7	Neg[b]	PosOTC[c]	DFM[d]	DFM & PosOTC[e]
Day 7 - 29	Neg	PosBMD[f]	DFM	DFM
Phase 2				
Day 29-36	Neg	PosOTC	DFM	DFM & PosOTC
Day 36 to 56	Neg	PosBMD	DFM	DFM
Phase 3				
Day 56 to 63	Neg	PosOTC	DFM	DFM & PosOTC
Day 63 to 84	Neg	PosBMD	DFM	DFM
Phase 4				
Day 84 to 98	Neg	BMD	DFM	DFM

[a]Three tons (24 lb/pig) of the OTC containing feed was fed at the beginning of Phase1, 2, and 3 for the POS and DFM2 treatments. This resulted in a 5 to 7 day dose of OTC containing diets being fed at the beginning of the phase. [b]Neg = No feed grade antibiotics or direct fed microbial. [c]PosOTC = Oxytetracyline at 400 g/ton. [d]DFM= Direct fed microbial. [e]DFM & PosOTC = Direct fed microbial and Oxytetracyline at 400 g/ton. [f]PosBMD = Bacitracin methylene diasalicylate (BMD) at 30 g/ton.

Table 2. Effects of a Direct Fed Microbial and Feed-Grade Antimicrobials on Growth, Efficiency, and Carcass Performance

	Treatment					
Item[a]	NEG	POS	DFM1	DFM2	SEM	P-Value
Average Weights, lb						
Day 0	99.4	99.1	99.2	99.5	0.39	0.84
Day 29	158.5	156.7	157	157.3	0.83	0.45
Day 56	205.1	202.8	202.3	200.9	1.53	0.3
Day 84	252.6	249.9	247.6	252.2	1.53	0.10
Day 98	270.8	266.3	268.5	266.4	2.25	0.46
Phase I, 0 to 29						
ADG, lb	2.03	1.98	1.99	1.99	0.02	0.42
ADFI, lb	4.45	4.45	4.45	4.45	0.11	0.99
F/G	2.21	2.26	2.25	2.26	0.05	0.88
Phase II, d 29 to 56						
ADG, lb	1.70	1.66	1.62	1.59	0.05	0.45
ADFI, lb	4.87	5.00	4.93	5.00	0.10	0.73
F/G	2.87	3.01	3.07	3.19	0.09	0.12
Phase 3 & 4, d 56 to 98[b]						
ADG, lb	1.64	1.61	1.65	1.69	0.02	0.11
ADFI, lb	5.54	5.37	5.40	5.38	0.09	0.54
F/G	3.38	3.34	3.29	3.18	0.06	0.18
Total (Day 0 - 98)						
ADG, lb	1.78	1.74	1.75	1.75	0.02	0.48
ADFI, lb	5.02	4.98	4.98	5.00	0.08	0.98
F/G	2.82	2.87	2.85	2.85	0.04	0.92
Carcass Data:						
% Yield[c]	75.5	74.7	75.2	75.0	0.3	0.32
Carcass wt, lb[d]	201.7	197	199.5	198.4	1.73	0.29
Backfat, in[d]	0.76	0.75	0.75	0.76	0.01	0.97
Loin depth, in[d]	2.15	2.17	2.17	2.14	0.02	0.61
% Lean[d]	53.6	53.8	53.8	53.6	0.2	0.84

[a]Each number is the mean of 10 pens (initially 25 barrows/pen). [b]Growth performance information for phases 3 and 4 were combined due to the short duration of the phase 4 feeding period. [c]Yield was calculated utilizing the live pen weights attained at the slaughter plant. [d]Backfat, loin depth, and percent lean were adjusted to a common carcass weight.

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THE INFLUENCE OF DIETARY ENERGY LEVEL ON THE RESPONSE TO BETAINE [1]

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

Summary

A total of 800 pigs were used to evaluate the influence of dietary energy level on the response to betaine in finishing pig diets. Dietary treatments were arranged in a 2 × 2 factorial with or without betaine and two energy density levels as the main effects. No betaine × energy interactions (P>0.05) were observed for the entire feeding period (51 to 210 lb) or for any of the three dietary phases. Pigs fed the high energy diets with added fat had (P<.05) greater ADG, lower ADFI, and improved F/G compared with pigs fed the low energy diets without added fat. Adding betaine to the diet had no influence on pig performance.

(Key Words: Betaine, Energy, Finishing Pigs.)

Introduction

Betaine is a chemical precursor to choline and similar to choline has activity biologically as a methyl donor. Research from the early 1990s from Australia indicated that pigs feeding dietary betaine had a 0.1" reduction in backfat depth. A subsequent study at K-State indicated a numerical trend for an improvement in ADG with no effect on F/G or carcass parameters. Other studies have failed to reveal a response in growth rate or carcass values when pigs were fed a corn-soy diet. A subsequent summary of betaine research indicated that a greater response to adding dietary betaine was achieved when feeding diets with lower energy content. Including betaine in a corn-soybean meal diet without added fat or choline resulted in a 7.6% improved feed efficiency (P<0.01) and increased average daily gain (P<0.01) in finishing pigs when fed for more than 38 days. Recent work reported by the University of Kentucky appears to agree with the summary, indicating that a better response was achieved when feeding lower energy diets with betaine. Therefore, the objective of this experiment was to determine if the response to added dietary betaine is influenced by the energy density of the diet.

Procedures

A total of 81,200 pigs (PIC barrows), initially weighing 51 lb, were 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. Each pen was equipped with a four-hole dry self-feeder and one cup waterer.

The finishing facility was a double curtain-sided, deep-pit barn that operated on natural ventilation during the summer and mechanical ventilation during the winter. Treatments were arranged in a 2 × 2 factorial, with or without betaine and two levels of increasing energy densities as the main effects, with seven pens per treatment. All diets were corn-soybean meal-based with

[1]Appreciation is expressed to Global Ventures for the use of pigs and facilities; and to Steve Rops, Mary Heintz, and Dr. Robert Powell for technical assistance.

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the lower energy diet containing no added fat and the high energy diet containing 5 to 6% added fat (Table 1). Betaine was included at 0.14% of the diet replacing corn in the treatment diets to obtain 1000 ppm of betaine, which was supplied by Finn Feeds International, Fenton, Missouri. Diets were fed in three phases: from 51 to 95 lb, 95 to 150 lb and 150 to 210 lb (Table 1). Each phase was fed for approximately 28 days. Vitamin and trace mineral levels were similar to KSU recommendations.

Pigs were weighed and feed disappearance was determined every 28 days. The ADG, ADFI, and F/G were determined for the performance data. Analysis of variance was used to analyze the data in a randomized complete block design using GLM procedures of SAS.

Results and Discussion

No betaine by energy interactions ($P>0.05$) were observed for the entire feeding period (51 to 210 lb) or for any of the three dietary phases (Table 2). Adding betaine to the diet did not affect pig performance; however, there was a significant response to energy density of the diet.

In phase 1, feed intake decreased ($P<0.01$) and feed efficiency improved significantly ($P<0.01$) with increasing dietary energy density. In phase 2 (95 to 150 lb), ADG was greater ($P<0.05$) for pigs fed the high-energy diet than pigs fed the low energy diet. Daily feed intake also was reduced ($P<0.05$) for pigs fed the high-energy diet leading to an improvement in feed efficiency ($P<0.01$) compared with pigs fed the low energy diet. The response in phase 3 (150 to 210 lb) was similar to the response during phase 2, with pigs fed the high-energy diet having increased ($P<0.05$) ADG and improved ($P<0.01$) F/G compared with pigs fed the low energy diet.

For the overall experiment, pigs fed the high-energy diet with added fat had higher ADG, lower ADFI, and improved F/G compared with pigs fed the low energy diets ($P<0.05$). There were no significant differences in weights at the end of phase 1 and 2, but at the end of phase 3 pigs fed the high energy density diet tended to be heavier ($P=0.087$) than those fed the low energy density diet. The responses of pigs fed the high energy diets is similar to previous research trials.

In the present trial from 50 to 210 lb, added fat resulted in 5 and 10% improvement in ADG and F/G, respectively. Energy density of the diet did not appear to influence the response to added dietary betaine. The results of this experiment failed to confirm the trends in ADG and F/G response to added fat in the diet observed with previous research at Kansas State University. Adding fat to the diet from 80 to 260 lb increased ADG and F/G by 1 and 2%, respectively, for each 1% added fat, similar to the response in this trial.

Based on the results of this experiment there appears to be little justification for adding betaine to growing-finishing swine diets. In contrast to some previous research, we failed to observe improvements in growth performance when adding betaine to corn-soybean meal diets regardless of dietary energy concentration. Energy density of the diet did not appear to influence the response to added dietary betaine. Pigs responded very favorably to the added fat in the diet in each phase, which agrees with previous research work.

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Table 1. Diet Composition

	Phase 1 (51 to 95 lb)		Phase 2 (95 to 150 lb)		Phase 3 (150 to 210 lb)	
	Energy Level		Energy Level		Energy Level	
Ingredients, %	Low	High	Low	High	Low	High
Corn[a]	72.68	62.95	72.68	64.56	78.77	71.15
Soybean meal	24.61	28.36	24.61	27.76	18.79	21.43
Choice white grease	–	6.00	–	5.00	–	5.00
Monocalcium phosphate (21% P)	1.08	1.05	1.08	1.05	0.90	0.88
Limestone	0.90	0.90	0.90	0.90	0.88	0.88
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.09	0.09	0.09	0.09	0.08	0.08
Trace mineral premix	0.15	0.15	0.15	0.15	0.10	0.10
Lysine•HCl	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis						
Lysine, %	1.11	1.20	1.12	1.19	0.89	0.95
ME, kcal/lb	1505	1628	1505	1606	1510	1613
Lysine:calorie ratio, g./mcal	3.17	3.17	3.17	3.17	2.67	2.67
Protein, %	17.6	18.5	17.6	18.4	15.4	16.0
Calcium %	0.65	0.65	0.65	0.65	0.59	0.59
Phosphorus, %	0.60	0.59	0.60	0.59	0.54	0.53
Available phosphorus, %	0.29	0.29	0.29	0.29	0.25	0.25

[a]BetaFin S6 (betaine; .14%) replaced corn in each diet to obtain the 1,000 ppm of betaine.

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Table 2. Growth Performance of Pigs Fed Diets with and without Betaine at Two Different Energy Levels from 15 to 210 lb[a]

	Betaine		Probability		Energy Level		Probability	
Item	Without	With	SEM	P<	Low	High	SEM	P<
Phase 1								
ADG, lb	1.71	1.75	0.02	0.30	1.74	1.73	0.02	0.81
ADFI, lb	3.30	3.31	0.06	0.88	3.42[b]	3.19[c]	0.05	0.01
F/G	1.92	1.89	0.01	0.20	1.97[b]	1.85[c]	0.02	0.01
Phase 2								
ADG, lb	2.10	2.03	0.03	0.11	2.01[b]	2.12[c]	0.03	0.02
ADFI, lb	5.09	5.01	0.07	0.48	5.20[b]	4.90[c]	0.08	0.01
F/G	2.43	2.49	0.03	0.27	2.60[b]	2.32[c]	0.03	0.01
Phase 3								
ADG, lb	1.96	2.00	0.03	0.35	1.91[b]	2.05[c]	0.03	0.01
ADFI, lb	4.81	4.92	0.12	0.51	4.97	4.75	0.11	0.18
F/G	2.47	2.46	0.05	0.93	2.61[b]	2.32[c]	0.05	0.01
Overall								
ADG, lb	1.93	1.90	0.02	0.36	1.87[b]	1.96[c]	0.02	0.01
ADFI, lb	4.43	4.43	0.05	0.99	4.55[b]	4.31[c]	0.07	0.02
F/G	2.30	2.33	0.03	0.35	2.43[b]	2.20[c]	0.03	0.01
Weight								
D 0	50.6	51.8	1.45	0.55	51.3	51.2	1.45	0.97
D 28	95.2	97.5	1.95	0.41	96.4	96.3	1.95	0.95
D 56	152.1	152.9	2.31	0.80	151.4	153.6	2.31	0.50
D 84	208.0	209.9	2.53	0.62	205.8	212.1	2.53	0.08

[a]Mean represents a total of 800 pigs, 25 pigs/pen and 8 pens/treatment. No betaine × energy interaction (P>0.10).
[b,c]Means within a row with different superscript letter differ (P<0.05).

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INFLUENCE OF INCREASING NIACIN ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF GROW-FINISH PIGS REARED IN A COMMERCIAL ENVIRONMENT [1]

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Summary

There were 1,243 growing pigs used to determine the effects of increasing dietary niacin on growth performance and meat quality of pigs reared in a commercial environment. The dietary treatments consisted of a control diet (no added niacin) or the control diet with 12.5, 25, 50, 100, or 500 g/ton of added niacin. Increasing dietary niacin decreased ADFI and improved F:G for the overall study. Increasing dietary niacin improved carcass shrink, ultimate pH, drip loss percentage, and loin color. Increasing dietary niacin up to 50 ppm improved feed efficiency, but higher concentrations (up to 50 ppm) decreased carcass shrink, and improved muscle quality in grow-finish pigs.

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

Introduction

Niacin has long been accepted as an essential vitamin for swine diets. However, the optimal dietary inclusion for finishing pigs receives considerable debate. According to a 1997 survey of vitamin inclusion rates, the average inclusion rate for niacin was 21 g/ton. The average of the 25% of the companies with the highest inclusion rate 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 health status, previous nutrition, vitamin levels in other ingredients and level of metabolic precursors in the diet.

Previous research at Kansas State University has shown no difference in growth performance due to added niacin and a minimal impact on pork quality. However, this could have been due to the high feed intakes of these hogs and that the control pigs were eating enough soybean meal to meet their requirement for niacin. Due to the limited information concerning the influence of niacin on meat quality and the wide range in supplementation rates in the commercial industry, we conducted this experiment to determine the effect of added niacin in finishing diets performance and meat quality characteristics of pigs raised on commercial facilities.

Procedures

One thousand two hundred forty-three PIC L337 × C22 barrows and gilts (initially 79.7 lb) were used in this experiment. Pens of approximately 26 pigs were blocked by average initial body weight and then randomly allotted to one of six dietary treatments with 4 pens/treatment/sex. Each pen was equipped with an eight hole stainless steel feeder and one cup waterer to provide ad libitum access to feed and water. Pigs were housed on totally slatted concrete floors in 10 × 18-ft pens. The finishing facility was a double curtain-sided, deep-pit barn that operated on manual ventilation during the

[1]Authors thank Global Ventures, Pipestone, MN for pig management.
[2]Food Animal Health and Management Center.
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summer and on automatic ventilation during the winter.

Pigs were fed the experimental corn-soybean meal diets in four phases (Table 1). The dietary treatments consisted of a control diet (no added niacin), or the control diet with 12.5, 25, 50, 100, or 500 g/ton additional niacin from niacinamide. The first three phases contained 6% choice white grease and all diets contained 0.15% L-lysine•HCl. All diets were fed in meal form and, vitamins and minerals except niacin were fed according to the KSU Swine Nutrition Guide.

Pig weights and feed disappearance were measured by pen every 14 d to calculate ADG, ADFI, and F/G. Diet phase changes occurred every 28 d. At the end of the growth study, one pig per pen was randomly selected and transported 450 miles to the KSU Meat Laboratory for harvest. The remaining pigs in each pen were tattooed to maintain pen identity and were transported to a commercial packing facility where standard carcass measurements were obtained.

Pigs transported to the KSU Meat Laboratory were harvested similar to that of a commercial facility. At 45 min postmortem, longissimus muscle (LM) pH was recorded at the 10th rib. Twenty-four hours postmortem, carcasses were weighed, ribbed, and one chop was removed (9th rib chop) and allowed to bloom for 30 minutes. A 2-person panel then assigned subjective color, marbling, wetness, and firmness scores to each chop. Immediately thereafter, Minolta color spectrophotometry data (CIE L*, a*, and b*) were measured in triplicate from the same chop. These values were then used to calculate a:b ratio, hue angle, and saturation index. The chops were then measured for loin eye area and dissected to obtain a 15-g center-cut sample. The samples were weighed and suspended on a fishhook in a sealed container for 24 hr to determine percentage drip loss.

All data from this experiment were analyzed using the MIXED procedure of SAS as a split-plot design with sex as the whole plot and dietary niacin as the subplot. The model included contrasts for linear and quadratic effects of unevenly spaced dietary niacin levels.

Results and Discussion

For the overall growth study, barrows had greater ($P<0.01$) ADG and ADFI ($P<0.07$) than gilts as would be expected (Table 2). From d 0 to 28 increasing dietary niacin decreased ADFI (quadratic, $P<0.01$) and improved F/G (quadratic, $P<0.003$) up to 100 g/ton additional niacin. From d 28 to 56, there were no differences in growth performance among treatments. Increasing dietary niacin up to 500 g/ton from d 56 to 84 improved (quadratic, $P<0.03$) F/G. Overall, increasing dietary niacin increased ADG (linear, $P<0.05$) and decreased ADFI (quadratic, $P<0.01$). Additionally, increasing dietary niacin up to 50 g/ton improved F/G (quadratic, $P<0.01$).

Regardless of slaughter facility, gilts were lighter ($P<0.01$) and had higher fat free lean indexes (FFLI) ($P<0.06$) than barrows (Table 3). Of the pigs harvested at the KSU Meat Laboratory, gilts were also leaner at the 10th rib ($P<0.03$) and tended to have a larger loin eye area ($P<0.06$) than barrows. Increasing niacin in the diet increased hot carcass weight (HCW) of gilts, but decreased HCW in barrows resulting in an interaction (sex × trt, $P<0.02$) for this response as well as cold carcass weight (CCW) (sex × trt, $P<0.04$). The interaction was primarily a function of pigs fed 500 g/ton niacin.

Barrows had more marbling ($P<0.02$) and higher a* values on the LM at the 10th rib ($P<0.05$) than gilts (Table 4). Therefore, a:b ratio was increased ($P<0.01$) for barrows, and hue angle was higher ($P<0.01$) for gilts. There were no other main effect differences for sex ($P>0.10$). Increasing niacin increased redness (a*) of LM at the 10th rib for barrows while decreasing a* when niacin was increased in gilts (trt × sex, $P<0.005$). Similarly, increasing niacin increased calculated saturation indexes for barrows, while decreasing these values for gilts (sex × trt, $P<0.03$). Because saturation index is dependent on L*, a*, and b* values, this is expected due to the effects of gender on a*

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values. Also, there was an interaction (sex × trt, P<0.005) for reflectance values on the 10th rib LM. Increasing niacin increased reflectance values for barrows, while decreasing values for gilts.

Increasing niacin increased (linear, P<0.01) 10th rib LM subjective color and wetness scores, while decreasing (linear, P<0.04) percentage drip loss of LM and L* values (linear, P<0.001). Increasing niacin also decreased (linear, P<0.10) redness (a*) and yellowness (b*, linear, P<0.04) of LM at the 10th rib. Saturation index was decreased (linear, P<0.04) as niacin increased, but this significance is only evident when looking at pigs fed 500 g/ton niacin. Increasing niacin in the diet increased (linear, P<0.02) carcass temperatures 45 min postmortem, which would indicate a slower temperature decline postmortem. In contrast, increasing niacin increased (linear, P<0.02) ultimate pH, which would normally suggest a more rapid decline in carcass temperature.

In conclusion, increasing niacin improved feed efficiency in this experiment contrary to a study where pigs were housed with four per pen in a research facility (2000 KSU Swine Day Report). Increasing niacin improved carcass shrink, and drip loss percentage in pigs, although it did not affect loin eye area or FFLI. Furthermore, increasing niacin improved subjective color, L* values (lightness), and ultimate pH of LM at the 10th rib, which would all indicate an improvement in pork quality.

The maximum response in feed efficiency was seen at 50 g/ton additional niacin; however, muscle quality indicators would suggest adding up to 500 g/ton additional niacin through the finishing phase to improve drip loss, color, and ultimate pH. More research is needed to determine the correct amount of niacin to add to maximize profitability from the growth performance and meat quality benefits found when adding niacin to grow-finish pig diets.

Table 1. Basal Diet Compositions

	Phases			
Item	D 0 to 28	D 28 to 56	D 56 to 84	D 84 to 117
Ingredient, %				
Corn	58.61	64.26	71.97	87.76
Soybean meal (46.5%)	32.44	26.99	19.70	10.06
Choice white grease	6.00	6.00	6.00	0.00
Monocalcium phosphate (21% P)	1.25	1.10	0.70	0.60
Limestone	0.90	0.90	0.90	0.85
Salt	0.35	0.35	0.35	0.35
Vitamin premix[a]	0.15	0.15	0.13	0.13
Trace mineral premix[b]	0.15	0.10	0.10	0.10
Lysine HCl	0.15	0.15	0.15	0.15
Chemical composition				
Lysine, %c	1.25	1.10	0.85	0.60
Tryptophan, %[c]	0.25	0.21	0.16	0.11
Calcium, %[c]	0.70	0.66	0.56	0.49
Phosphorus, %[c]	0.65	0.60	0.48	0.44
Total niacin, mg/kg[d]	24.9	24.8	24.5	24.6
Available niacin, mg/kg[e]	11.0	9.2	6.7	3.4

[a]Provided dietary treatments of 0, 13, 28, 55, 110, or 550 mg/kg niacin. Also provided 6,600 USP vitamin A, 990 USP vitamin D_3, 26 IU vitamin E, 2.64 mg B_{12}, 6 mg riboflavin, and 20 mg pantothenic acid per kg of diet from d 0 to 56, and 83% of these levels from d 56 to 117. [b]Provided 165 mg zinc, 165 mg iron, 40 mg manganese, 17 mg copper, 0.30 mg iodine, 0.30 mg selenium per kg of diet from d 0 to 28, and 67% of these levels from d 28 to 117. [c]Calculated content, NRC (1998). [d]Analyzed content. [e]Calculated by subtracting niacin in corn (NRC, 1998) from total analyzed content.

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Table 2. Effects of Niacin on Growth Performance in Grow-Finish Pigs[a]

	Niacin, g/ton							Probabilities, P<			
Item	0	12.5	25	50	100	500	SEM	Trt	Sex × Trt	Linear	Quadratic
D 0 to 28											
ADG, lb	1.82	1.88	1.86	1.85	1.85	1.85	0.030	0.82	0.20	0.98	0.83
ADFI, lb[c]	3.37	3.64	3.58	3.46	3.43	3.57	0.065	0.12	0.82	0.86	0.01
F/G[c f]	2.00	1.94	1.92	1.88	1.85	1.93	0.035	0.06	0.72	0.81	0.003
D 29 to 56											
ADG, lb	1.96	1.94	1.89	2.00	1.85	1.88	0.036	0.05	0.18	0.15	0.20
ADFI, lb[be]	4.86	4.74	4.64	4.57	4.61	4.57	0.095	0.24	0.38	0.17	0.11
F/G	2.49	2.45	2.47	2.29	2.49	2.44	0.075	0.44	0.65	0.97	0.78
D 57 to 84											
ADG, lb	1.45	1.53	1.44	1.49	1.51	1.51	0.038	0.47	0.28	0.37	0.54
ADFI, lb[be]	5.14	5.06	4.94	4.80	4.91	4.82	0.110	0.21	0.05	0.13	0.14
F/G[ce]	3.57	3.30	3.44	3.23	3.25	3.18	0.074	0.01	0.39	0.01	0.03
D 85 to 117											
ADG, lb	1.50	1.51	1.54	1.52	1.46	1.43	0.038	0.43	0.97	0.07	0.59
ADFI, lb[d]	5.38	5.44	5.60	5.32	5.16	5.21	0.109	0.08	0.35	0.08	0.08
F/G	3.58	3.61	3.66	3.51	3.52	3.64	0.079	0.73	0.52	0.61	0.29
D 0 to 117											
ADG, lb[d]	1.67	1.71	1.68	1.71	1.66	1.66	0.013	0.05	0.69	0.05	0.50
ADFI, lb[ce]	4.77	4.75	4.72	4.56	4.55	4.57	0.060	0.03	0.24	0.05	0.01
F/G[ce]	2.85	2.78	2.81	2.67	2.73	2.75	0.030	0.01	0.37	0.32	0.01
Initial wt, lb	79.7	79.8	79.7	79.4	79.7	79.8	0.58	0.99	0.45	0.85	0.87
Final wt, lb	278.3	283.9	276.6	282.9	276.5	277.1	1.90	0.02	0.92	0.17	0.42

[a]Values are representative of initially 1243 pigs (79.7 lb). [b]Niacin linear 0 to 100 g/ton (P<0.05). [c]Niacin linear 0 to 100 g/ton (P<0.01). [d]Niacin quadratic 0 to 100 g/ton (P<0.06). [e]Control vs. 500 g/ton (P<0.05). [f]100 niacin vs. 500 g/ton (P<0.08).

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Table 3. Effects of Niacin on Carcass Characteristics in Grow-Finish Pigs

	Niacin, g/ton							Probabilities, P<			
Item	0	12.5	25	50	100	500	SEM	Trt	Sex × Trt	Linear	Quadratic
Values from pigs harvested at KSU Meat Laboratory											
HCW, lb	188.4	194.6	193.4	190.7	190.4	193.1	3.05	0.71	0.04	0.68	0.76
Dress, %	75.2	75.2	76.1	74.6	74.8	75.7	0.57	0.48	0.54	0.55	0.27
CCW, lb	186.2	193.5	191.8	188.9	189.1	191.1	3.01	0.60	0.03	0.73	0.86
Shrink, %	1.20	0.58	0.86	0.97	0.68	1.01	0.145	0.06	0.34	0.51	0.14
FFL, %	53.54	54.42	53.10	52.65	51.85	53.05	1.194	0.76	0.76	0.76	0.18
BF											
First, in[a]	1.47	1.49	1.58	1.47	1.54	1.40	0.073	0.58	0.54	0.23	0.45
Last, in[a]	0.96	0.85	0.97	0.92	1.00	0.93	0.048	0.31	0.85	0.95	0.20
LLV, in[a]	0.60	0.56	0.64	0.58	0.65	0.59	0.054	0.84	0.95	0.88	0.49
Tenth, in[a]	0.74	0.69	0.80	0.77	0.80	0.76	0.062	0.81	0.96	0.83	0.35
Avg., in[a]	1.01	0.97	1.06	0.99	1.06	0.97	0.055	0.65	0.88	0.55	0.33
Length, in[a]	34.2	34.3	33.5	34.1	34.0	33.8	0.32	0.42	0.12	0.45	0.88
LEA, in^{2a}	7.00	7.16	7.21	6.73	6.35	6.85	0.433	0.74	0.54	0.72	0.16
Values from pens of pigs harvested at commercial facilities											
HCW, lb	212.0	213.5	212.1	211.8	209.9	210.4	1.36	0.48	0.33	0.21	0.18
Dress, %	0.77	0.77	0.77	0.77	0.77	0.76	0.004	0.20	0.09	0.64	0.21
FFLP	52.62	52.36	52.43	52.43	52.51	52.22	0.256	0.92	0.29	0.39	0.92
Avg. BF, in[b]	0.66	0.67	0.68	0.67	0.68	0.69	0.015	0.76	0.70	0.19	0.56
Loin depth, in[b]	2.32	2.32	2.37	2.30	2.35	2.31	0.024	0.40	0.01	0.55	0.61

[a]HCW used as covariate (191.8 lb).
[b]HCW used as covariate (211.6 lb).

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Table 4. Effects of Niacin on Meat Quality in Grow-Finish Pigs

	Niacin, mg/kg							Probabilities, P<			
Item	0	12.5	25	50	100	500	SEM	Niacin	Sex × Trt	Lin.	Quadratic
Marbling[a]	1.1	1.2	1.2	1.4	1.3	1.6	0.21	0.39	0.86	0.15	0.73
Color[ahi]	3.9	3.8	3.9	3.3	4.2	4.4	0.19	0.86	0.25	0.01	0.89
Wetness[bj]	2.4	2.6	2.4	2.4	2.7	2.9	0.13	0.15	0.53	0.01	0.45
Firmness[c]	2.4	2.4	2.5	2.3	2.4	2.6	0.18	0.75	0.97	0.42	0.82
Drip loss, %[i]	2.00	1.90	1.93	1.90	1.23	0.80	0.469	0.39	0.29	0.04	0.41
L*[dhj]	53.12	53.60	53.14	53.95	51.43	49.77	0.733	0.36	0.08	0.01	0.35
a*[di]	8.22	7.57	8.00	8.15	8.07	7.27	0.374	0.33	0.02	0.10	0.54
b*[di]	13.33	13.15	12.90	14.24	12.89	12.35	0.404	0.61	0.06	0.04	0.76
a:b	0.62	0.58	0.62	0.57	0.62	0.59	0.022	0.42	0.09	0.82	0.77
Hue angle[e]	58.35	60.07	58.21	60.59	58.21	59.40	0.917	0.35	0.07	0.80	0.80
Sat. Index[f]	15.67	15.19	15.20	16.44	15.24	14.35	0.496	0.48	0.03	0.04	0.63
630/580[dh]	2.59	2.47	2.49	2.54	2.60	2.54	0.061	0.37	0.005	0.83	0.38
45 min pH	6.42	6.42	6.32	6.28	6.29	6.32	0.127	0.51	0.93	0.76	0.38
45 min temp[gj]	32.9	34.4	34.2	34.3	35.5	36.2	0.79	0.03	0.45	0.02	0.13
24 hr pH[gj]	5.67	5.73	5.77	5.76	5.85	5.94	0.049	0.01	0.10	0.001	0.06
24 hr temp	0.1	0.2	-0.3	-0.1	0.2	-0.3	0.25	0.64	0.98	0.37	0.64

[a]NPPC reference cards. [b]Scale of 1 to 3; 1-cut surface distorts easily (visibly soft), 2-cut surface tends to hold shape, 3- cut surface very smooth (no distortion of shape). [c]Scale of 1 to 3; 1-excessive fluid pooling on cut surface, 2-cut surface moist - little or no free water, 3-cut surface exhibits no free water. [d]Measure of lightness (L*), redness (a*), or yellowness (b*); reflectance values (%R630/%R580). [e]Measure of color angle (higher value is redder). [f]Measure of color intensity. [g]Niacin linear 0 – 100 g/ton (P<.06). [h]Niacin quadratic 0 – 100 g/ton (P<.10). [i]Control vs. 500 g/ton niacin (P<.10). [j]Control vs. 500 g/ton niacin (P<.01).

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EVALUATION OF DIFFERENT COPPER SOURCES AS A GROWTH PROMOTER IN SWINE FINISHING DIETS [1]

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

Summary

Two trials were conducted to determine the effects of added copper from copper sulfate or copper chloride on performance of growing-finishing pigs. A total of 2,277 pigs with an initial weight of 71.6 lb were used in a commercial research facility in southwest Minnesota. Adding copper to the diet improved performance during the first two weeks in the finishing barn regardless of copper source or level. The results of these experiments indicate that low levels of copper chloride or copper sulfate (50 to 100 ppm) can be an effective and economical growth promoter when fed for the first two weeks to growing-finishing pigs.

(Key Words: Growth Promoter, Copper Sulfate, Copper Chloride, Grower-Finisher Pigs.)

Introduction

Many swine production systems have used copper sulfate as a growth promoter in growing and finishing diets. Recent research indicates that tribasic copper chloride is as effective as copper sulfate as a growth promoter in nursery pig diets. Previous trials have shown that low levels of tribasic copper chloride yield similar results as higher levels of copper sulfate. Because of the lower inclusion rate, adding copper chloride may be more cost effective than copper sulfate for growth promotion. The lower inclusion rate also would result in less copper excretion in swine waste. In addition, copper chloride is thought to be less oxidative and thus, should result in less corrosion to feeders and gating. Therefore, the objective of these trials was to evaluate low levels of copper chloride and copper sulfate as growth promoters in growing-finishing diets.

Procedures

Both experiments were conducted in a commercial research facility in southwest Minnesota. Pigs were randomly allotted to the dietary treatments in a randomized complete block design in both experiments. Each pen contained one self-feeder and nipple waterer to allow ad libitum access to feed and water. There were approximately 28 pigs per pen with the same number of pigs per pen within each block. Pigs were weighed and feed disappearance was determined approximately every 14 days to calculate ADG, ADFI, and feed efficiency.

Experiment 1. A total of 1,100 pigs (initially 74.2 lb) were used. Pigs were allotted to one of five dietary treatments with 8 replications (pens) per treatment (4 per gender). Diets were fed in four phases in order to more closely match nutrient requirements of the pigs. The phases were from d 0 to 31, 31 to 59, 59 to 86, and 86 to 115 (Table 1). Within each phase, treatment diets consisted of a control diet with no added copper, three diets with 50, 100, and 200 ppm of added

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[2]Food Animal Health and Management Center.

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copper from copper chloride and a single diet with 200 ppm of added copper from copper sulfate. Copper replaced corn in the control diet.

Experiment 2. A total of 1,177 gilts (initially 68.9 lb) were used in this experiment. Pigs were allotted to one of seven dietary treatments in a randomized complete block design with six pens per treatment. Diets were provided in two phases from d 0 to 27 and d 27 to 56. Diets consisted of a control diet with no added copper and control plus 50, 100, or 200 ppm of added copper from either copper chloride or copper sulfate (Table 2).

Results and Discussion

Experiment 1. Adding either copper source to the diet reduced (P<0.02) ADFI and improved (P<0.05) F/G during phase 1 (d 0 to 31). When copper chloride was added to the diet, the greatest improvement in ADFI and F/G occurred with the addition of the first 50 ppm of copper. Adding copper to the diet caused a similar reduction (P<0.05) in ADFI during phase 3. Copper did not consistently influence ADG; however, there was a trend (P<0.12) for improved ADG during phase 2 and 4 when copper was added to the diet.

For the overall experiment, ADG was improved as either copper source was added to the diet (linear, P<0.07 for copper chloride and P<0.003 for copper sulfate). Pigs fed either copper source had reduced (P<0.06) ADFI and improved (P<0.003) F/G for the overall trial. The feed intake and feed efficiency response to increasing copper chloride was quadratic; the maximal response was observed in pigs fed 50 ppm, with no further improvement through the higher levels.

Experiment 2. Pigs fed either copper source had greater (P<0.01) ADG during the first two weeks of the experiment compared to pigs fed the control diet. There were no differences between copper sources and no response to copper level indicating that the maximal response was achieved with the inclusion of the first 50 ppm of copper. Adding copper sulfate to the diet reduced (P<0.03) ADFI and copper chloride tended to improve (P<0.07) feed efficiency from d 0 to 14.

From d 14 to 27, pigs fed copper sulfate had greater (P<0.04) ADG than pigs fed copper chloride. However, ADG for pigs fed either copper source was not different from pigs fed the control diet. Neither copper source nor level had any affect on ADFI or F/G.

From d 27 to 42, pigs fed diets containing copper chloride had decreased (P<0.03) ADFI but improved (P<0.04) F/G compared with pigs fed the diets containing copper sulfate. Similar to the response from d 14 to 27, neither copper source influenced ADG, ADFI, or F/G compared to the control diet. Neither copper source nor level influenced performance from d 27 to 56.

For the overall experiment, ADG was greater (P<0.05) for pigs fed copper sulfate compared to those fed the control diet. They also tended to have greater (P<0.08) ADG than pigs fed the diets containing copper chloride. Pigs fed diets containing copper sulfate had greater (P<0.02) ADFI than pigs fed diets containing copper chloride; however, neither source influenced ADFI compared to pigs fed the control diet. Also, neither copper source influenced F/G compared to the control diet; however, there was a level by source interaction (P<0.05). The reason for the interaction is that F/G improved with increasing levels of copper chloride while no distinct pattern was found with increasing levels of copper sulfate.

In conclusion, adding low levels of copper to diets during the first four weeks of the growing-finishing phase appears to provide an advantage in gain and feed efficiency. There is not an advantage to use copper chloride as a replacement for copper sulfate. Because of the low cost of copper and the improvements in ADG and feed efficiency, this practice may offer an economic benefit for the producer. Added copper during the late finishing phase does not appear to provide any significant advantage in gain or feed conversion.

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Table 1. Composition of Diets in Experiment 1				
Ingredient	d 0 to 31	d 31 to 59	d 59 to 86	d 86 to 115
Corn	58.98	64.43	75.43	87.75
Soybean meal (46.5%)	32.41	26.97	16.09	10.07
Choice white grease	6.00	6.00	6.00	0.00
Monocalcium phosphate (21% P)	1.08	1.02	1.02	0.75
Limestone	0.84	0.87	0.81	0.85
Salt	0.35	0.35	0.35	0.35
Vitamin premix	0.09	0.07	0.06	0.04
Trace mineral premix	0.10	0.12	0.10	0.05
Lysine@HCl	0.15	0.15	0.15	0.15
Copper chloride or sulfate[a]	- - -	- - -	- - -	- - -
TOTAL	100.00	100.00	100.00	100.00
Calculated Analysis				
Desired lysine, %	1.25	1.10	.80	
Isoleucine:lysine ratio	67%	68%	65%	
Leucine:lysine ratio	142%	148%	167%	
Methionine:lysine ratio	25%	26%	30%	
Met & Cys:lysine ratio	54%	56%	62%	
Threonine:lysine ratio	62%	62%	65%	
Tryptophan:lysine ratio	20%	19%	19%	
Valine:lysine ratio	77%	78%	82%	
ME, kcal/lb	1,628	1,629	1,633	
Protein, %	20.10	18	13.9	
Calcium, %	0.65	0.63	0.57	
Phosphorus, %	0.61	0.58	0.54	
Available phosphorus, %	0.30	0.28	0.27	
Lysine:calorie ratio, g/Mcal ME	3.48	3.06	2.22	

[a]Copper source replaced corn in the control diets.

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Table 2. Composition of Diets in Experiment 2		
Ingredient, %	d 0 to 27	d 27 to 56
Corn	59.29	66.85
Soybean meal (46.5%)	32.04	24.84
Choice white grease	6.00	6.00
Monocalcium phosphate (21% P)	1.05	0.85
Limestone	0.90	0.80
Salt	0.35	0.35
Vitamin premix	0.08	0.06
Trace mineral premix	0.15	0.10
Copper chloride or sulfate	- - -	- - -
Lysine@HCl	0.15	0.15
TOTAL	100.00	100.00
Calculated Analysis		
Lysine, %	1.25	1.05
Isoleucine:lysine ratio	67%	66%
Leucine:lysine ratio	141%	151%
Methionine:lysine ratio	25%	27%
Met & cys:lysine ratio	54%	57%
Threonine:lysine ratio	62%	63%
Tryptophan:lysine ratio	20%	19%
Valine:lysine ratio	77%	79%
ME, kcal/lb	1,627	1,634
Protein, %	20.1	17.36
Calcium, %	0.66	0.57
Phosphorus, %	0.61	0.54
Available phosphorus, %	0.29	0.24
Lysine:calorie ratio, g/Mcal ME	3.48	2.91

[a]Copper source replaced corn in the control diets.

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Table 3. Growth Performance of Finishing Pigs fed Various Copper Sources (Exp. 1)[a]

		CuCl			$CuSO_4$		CuCl		Control vs. $CuSO_4$
Item	Control	50	100	200	200	SEM	Linear	Quadratic	
Period I, d 0 to 31									
ADG, lb	1.83	1.84	1.78	1.89	2.02	0.073	0.58	0.44	0.08
ADFI, lb	4.05	3.76	3.72	3.76	3.77	0.067	0.02	0.01	0.01
F/G	2.25	2.09	2.13	2.00	1.88	0.075	0.05	0.70	0.002
Period II, d 31 to 59									
ADG, lb	1.69	1.68	1.70	1.78	1.77	0.036	0.08	0.47	0.12
ADFI, lb	4.10	3.81	3.88	3.92	4.02	0.103	0.44	0.13	0.57
F/G	2.43	2.28	2.29	2.22	2.28	0.081	0.11	0.50	0.20
Period III, d 59 to 86									
ADG, lb	1.64	1.75	1.67	1.78	1.65	0.047	0.09	0.95	0.92
ADFI, lb	5.31	5.18	5.05	4.99	5.01	0.107	0.04	0.45	0.05
F/G	3.24	2.96	3.02	2.81	3.06	0.106	0.02	0.61	0.26
Period IV, d 86 to 115									
ADG, lb	1.05	1.14	1.20	1.03	1.16	0.047	0.57	0.01	0.12
ADFI, lb	3.98	4.03	3.97	4.01	3.93	0.106	0.92	0.96	0.70
F/G	3.84	3.61	3.33	3.91	3.48	0.177	0.70	0.02	0.16
Overall, d 0 to 115									
ADG, lb	1.56	1.61	1.59	1.63	1.66	0.022	0.07	0.58	0.003
ADFI, lb	4.34	4.17	4.13	4.15	4.16	0.063	0.06	0.08	0.05
F/G	2.79	2.59	2.59	2.55	2.51	0.047	0.003	0.05	0.001
Final Wt.	254.86	257.9	258.4	260.0	262.3	1.70	0.05	0.51	0.004

[a]A total of 1,100 pigs (20 pens of barrows and 20 pens of gilts with 26 to 28 pigs per pen and with eight replications, four per gender for each treatment) with an average initial weight of 74.4 lb were used for this experiment.

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Table 4. Growth Performance of Pigs Fed Increasing Copper Chloride or Copper Sulfate (Exp. 2)[a]

	Control	Copper Chloride			Copper Sulfate			
Item	No Cu	50	100	200	50	100	200	SEM
D 0 to 14								
ADG, lb	1.83	2.00	1.91	2.04	2.01	1.99	2.02	0.04
ADFI, lb	3.29	3.42	3.39	3.35	3.48	3.41	3.53	0.07
F/G	1.80	1.72	1.78	1.65	1.73	1.71	1.75	0.04
D 14 to 27								
ADG, lb	2.10	2.05	2.08	2.10	2.13	2.19	2.15	0.04
ADFI, lb	4.34	4.35	4.26	4.38	4.36	4.37	4.46	0.07
F/G	2.07	2.12	2.05	2.08	2.05	2.01	2.08	0.05
D 27 to 42								
ADG, lb	1.82	1.81	1.84	1.80	1.86	1.72	1.81	0.04
ADFI, lb	4.55	4.54	4.52	4.42	4.59	4.64	4.62	0.07
F/G	2.50	2.51	2.47	2.46	2.48	2.70	2.55	0.06
D 27 to 56								
ADG, lb	1.87	1.75	1.82	1.86	1.85	1.84	1.88	0.04
ADFI, lb	4.45	4.32	4.32	4.48	4.39	4.48	4.44	0.09
F/G	2.38	2.49	2.38	2.41	2.37	2.44	2.36	0.06
Overall, d 0 to 56								
ADG, lb	1.90	1.90	1.91	1.95	1.96	1.93	1.96	0.02
ADFI, lb	4.16	4.16	4.13	4.16	4.21	4.23	4.26	0.04
F/G	2.19	2.19	2.17	2.14	2.15	2.19	2.17	0.02

[a]A total of 1,177 gilts with an average initial wt of 68.9 lb were used in the experiment. The values represent the means of six pens per treatment and 28 pigs per pen.

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Table 5. Probability Values for Growth Performance of Pigs Fed Increasing Copper Chloride or Copper Sulfate (Exp. 2)[a]

	P-Value			Control vs.	
Item	Level	Source	Level* Source	Copper Chloride	Copper Sulfate
D 0 to 14					
ADG	0.11	0.36	0.39	0.007	0.001
ADFI	0.79	0.19	0.58	0.24	0.03
F/G	0.47	0.61	0.12	0.07	0.13
D 14 to 27					
ADG	0.63	0.04	0.82	0.73	0.19
ADFI	0.34	0.25	0.78	0.91	0.46
F/G	0.61	0.45	0.84	0.84	0.70
D 27 to 42					
ADG	0.41	0.55	0.14	0.93	0.59
ADFI	0.65	0.03	0.54	0.50	0.41
F/G	0.23	0.04	0.08	0.76	0.24
D 27 to 56					
ADG	0.29	0.14	0.56	0.20	0.79
ADFI	0.53	0.40	0.51	0.49	0.91
F/G	0.76	0.45	0.37	0.49	0.90
Overall, d 0 to 56					
ADG	0.26	0.08	0.55	0.52	0.05
ADFI	0.68	0.02	0.75	0.79	0.12
F/G	0.36	0.65	0.05	0.17	0.30

[a]A total of 1,177 gilts with an average initial wt of 68.9 lb were used in the experiment. The values represent the means of six pens per treatment and 28 pigs per pen.

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NUTRIENT COMPOSITION OF KANSAS SWINE LAGOONS AND HOOP BARN MANURE [1]

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

Summary

A total of 236 lagoon and 35 hoop barn manure samples were collected during 2000 from Kansas swine operations to determine the effects of production phase and season of the year on their nutrient concentration. Lagoon analyses revealed that nitrogen concentrations were lower during the summer and fall seasons compared to winter and early spring. In addition, levels of nitrogen were highest in nursery, wean to finish, and finishing lagoons compared with sow and farrow-to-finish lagoons. Phosphorus levels for all lagoons increased from February until June, but then declined steadily throughout the remainder of the year. The concentration of phosphorus also was highest for wean-to-finish and finishing lagoons and the lowest for farrow-to-finish lagoons. No seasonal changes in nitrogen and phosphorus concentrations were observed in manure from hoop barns. Therefore, season and type of production phase affects the nutrient content of Kansas swine lagoons, and producers will benefit from obtaining individual analyses from their lagoons when developing nutrient management plans rather than utilizing published reference values.

(Key Words: Pig, Lagoon, Hoop Barn.)

Introduction

Environmental stewardship by livestock producers throughout the world has become an emerging issue to help preserve and maintain the environment. To ensure proper management of livestock waste, nutrient profiles of various forms and types of manure have been established to help livestock operators accurately apply manure to land. This practice allows crops or forages to utilize the nutrients from the manure thereby decreasing the need for chemical fertilizers. Thus, accurate and detailed nutrient profiles must be obtained to correctly distribute manure so that a deficiency or excess of a given nutrient does not occur. Currently, many sources of nutrient reference values are available to provide average concentrations of various types of manure from different livestock species. Published values are a source of information that producers can use to determine the amount of land needed for manure application or for comparison to their on-farm manure analysis. However, these reference values represent manure samples from across the United States and are from samples compiled during the past two decades. The majority of these published values may not reflect manure nutrient profiles from Kansas swine operations from the recent changes in management practices (phase feeding, use of phytase, reduced particle size) or differences in nutrient concentrations associated with different types of production phases or manure handling systems. In addition, published values do not account for differences that may occur with the season of the year, which may lead to a misrepresentation of the actual nutrient profile for producers. Therefore, it was our objective to determine the effects of produc-

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tion phase and season of the year on nutrient concentration of swine lagoons and hoop barn manure from Kansas swine operations.

Procedures

Lagoons. Samples from five different types of production systems were taken six times over the year 2000 to determine changes in nutrient and mineral concentrations. The different operations were classified as: 1) sow; 2) nursery; 3) wean to finish; 4) finish; and 5) farrow to finish, with a total of 9, 8, 7, 10, and 8 lagoons sampled from each phase of production, respectively. Our classification was based on the type of facility sending effluent into the lagoon. The lagoons used collected waste from only gestation and farrowing facilities (sow), from only nursery facilities (nursery), from only nursery and finishing facilities (wean to finish), from only finishing facilities (finishing), or from combined gestation, farrowing, nursery and finishing facilities (farrow-to-finish). Lagoons were sampled in February, April, June, August, October, and December.

The lagoons used were in different geographic locations across Kansas. Because our goal was to develop average nutrient concentrations from lagoons within a classification, we did not distinguish between waste handling systems within a classification.

We provided an on-farm demonstration of the technique used to sample lagoons. Thus, all swine operations had employees that were trained in proper sampling technique. In addition, all participants collected samples at a uniform time (2nd Tuesday of the month sampled). For collecting samples from lagoons, we designed and constructed a sampler that was distributed to all participants in the project. The sampler contained two separate pieces of 1 inch PVC pipe. First, a 6 inch piece was capped at one end, filled to volume with sand, and attached via a ½ inch threaded solid-centered coupler to the second piece of pipe, which was 12 inches in length (Figure 1). This portion held the liquid from the lagoon during collection. In addition, a 1 inch threaded screw cap was attached to the top of the 12 inch pipe, with five 11/32 inch holes drilled into the cap to allow liquid to enter the pipe once it was submerged in the lagoon. A 40 ft nylon rope was attached via a galvanized metal clamp just below the screw cap. Positioning the rope in this manner was to prevent loss of the liquid once it was retrieved from the lagoon. The sampler was weighted with sand so that it would sink approximately 6 to 8 ft before being filled to volume of liquid. Four samples were taken from different locations throughout each lagoon and combined. The combined samples were then thoroughly mixed and sub-sampled for chemical analysis. No samples were taken within 40 ft of any inlet pipes entering the lagoon from the production facilities. All samples were shipped to the laboratory the same day in which they were taken.

Hoop Barns. Samples from six hoop barn sites were collected at the same time as lagoons. All manure from the production sites used in this study originated from growing and/or finishing pigs. A least 5 samples were collected approximately 18 inches from the outside of the manure pile to reduce the incidence of weather effects. The samples were combined and mailed to the laboratory on the day of collection for analysis. The manure piles sampled throughout the year ranged from newly removed manure from the hoop barn to manure piles that had been stored for more then one year.

Sample Analysis. All manure samples were analyzed at Platte Valley Laboratories, Inc., Gibbon, NE through AOAC procedures. All lagoon and hoop barn samples were analyzed for nitrate, ammonium, and total nitrogen. Organic nitrogen was calculated by subtracting ammonium and nitrate nitrogen from the total nitrogen. In addition, concentrations of phosphorus, potassium, calcium, sodium, chloride, magnesium, sulfur, copper, zinc, iron, and manganese were analyzed. Phosphate and potash were calculated from the concentrations of phosphorus and potassium, respectively. In addition, percentage solids, pH, and electrical conductivity were measured. Carbonate and bicarbonate concentrations also were measured on lagoon samples, but not hoop barn samples.

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Statistical Analyses. Statistical analyses were performed using the MIXED procedures of SAS. Individual samples were used as the experimental unit, with month used as a repeated measure to determine seasonal difference. Orthogonal contrasts were used to determine linear and quadratic effects of nutrient concentrations from February to December. In addition, the least square means test was applied to determine statistical differences between production phases. No phase by month interactions occurred, thus main effects of production phase and month of analysis results are reported.

Results and Discussion

Lagoon Concentration by Production Phase. Nutrient concentrations from lagoons on wean-to-finish and finishing operations were higher for the majority of nutrients compared to sow and farrow-to-finish operations (Table 1). Samples from nursery lagoons usually had intermediate values; except for trace minerals, for which they had the highest concentrations.

For total nitrogen, lagoons from finishing and wean-to-finish facilities had greater concentrations ($P<0.05$) compared to sow and farrow-to-finish lagoons (Table 1). In addition, lagoons from sow and farrow-to-finish operations had approximately 39 and 48% less total nitrogen compared to nursery lagoons, respectively, although the differences were not significant ($P>0.05$). For ammonium nitrogen, farrow to finish lagoons had lower ($P<0.05$) levels than wean-to-finish and finishing lagoons. Furthermore, the level of nitrate nitrogen was less than 1 ppm for all production phases, thus indicating that concentrations of nitrates is low in the liquid portion sampled from the lagoons.

Phosphorus concentrations in farrow-to-finish lagoons were lower ($P<0.05$) by approximately 65% compared to lagoons from wean-to-finish operations (Table 1). Although not significantly different ($P>0.05$), phosphorus concentrations from nursery (223 ppm) and finishing (246 ppm) lagoons were higher while concentrations from sow farms had levels (141 ppm) below that of the overall average of 203 ppm for all samples. Phosphate levels followed an identical pattern as that of phosphorus, as it was calculated from the phosphorus levels. For potassium, sow lagoons contained lower ($P<0.05$) concentrations then wean-to-finish and finishing lagoons, while levels in nursery and farrow-to-finish lagoons were intermediate. Potash concentrations were calculated from the analyzed potassium concentrations, thus, differences followed the same pattern as potassium. Farrow-to-finish lagoons had lower ($P<0.05$) concentrations of calcium then nursery, wean-to-finish, and finishing lagoons, while sow lagoons had lower ($P<0.05$) levels then finishing lagoons. For sodium, no differences between phases of production were detected. However, sow lagoons had a lower concentration ($P<0.05$) of chloride and magnesium compared to wean-to-finish and finishing lagoons, with nursery and farrow-to-finish lagoons having intermediate concentrations. In addition, sulfur concentrations were dramatically reduced ($P<0.05$) in lagoons from sow and farrow-to-finish operations compared to the other three types of production phases.

For the trace minerals (copper, zinc, iron, and manganese), sow and farrow-to-finish lagoons had the lowest concentrations compared to the other production phases (Table 1). In addition, concentrations of all minor nutrients except manganese were the highest in nursery lagoons. For copper and iron concentrations, nursery lagoons had a higher level ($P<0.05$) compared to sow and farrow-to-finish lagoons. In addition, the zinc concentration in nursery lagoons was higher ($P<0.05$) then all other phases of production, being approximately 59% higher (40.7 vs. 16.8 ppm) than the combined mean of all phases. For manganese, sow and farrow-to-finish lagoons contained lower ($P<0.05$) concentrations compared to lagoons from the other three production phases.

Bicarbonate, which is an indicator of dissolved carbon dioxide when the pH of the sample is between 6.4 and 10.2, was significantly lower ($P<0.05$) for sow and farrow-to-finish lagoons compared to the other production phases (Table 1). However, the carbonate level was less than 1 ppm for all samples,

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which would be logical, as it is an indicator of dissolved carbon dioxide when the pH of the sample is over 10.2. Average pH values ranged from 7.7 to 7.8 for the samples from the different production phases. Electrical conductivity, which measures the ability of a substance to carry an electrical current and is directly correlated to the amount of dissolved salts in the sample was higher ($P<.05$) for wean-to-finish and finish lagoons compared with farrow-to–finish lagoons. The percentage of solids in the samples was higher ($P<0.05$) for wean-to-finish and finishing lagoons than sow and farrow-to-finish lagoons.

Differences in nutrient concentrations between production phases may be associated with different management, nutrition, and lagoon types associated with each phase. For the farrow-to-finish operations, many of the locations utilized both a primary and secondary lagoon system, or one large lagoon. Use of these types of lagoons may have resulted in decreased concentrations of nutrients, which would be correlated with the percentage solids, also reduced compared to nursery, wean-to-finish, and farrow-to-finish lagoons. In addition, sow lagoons were also typically lower in nutrient concentration than the other production phases, which may be because the breeding herds produce less manure per animal body weight than growing-finishing pigs. This would help explain the reduction in percentage solids with sow and farrow-to-finish lagoons compared to the other phases of production as well. Furthermore, as swine increase in age they become less efficient in the utilization of nutrients when fed ad libitum. This may help explain the increased level of nutrients found in wean-to-finish and finishing lagoons. Also, improper management (feeder adjustment) and nutrition (overformulation of diets) may have increased nutrient levels for these two production phases. Increased concentrations of certain trace minerals in nursery lagoons, especially for zinc and copper, would be associated with nutrition practices that use these minerals as growth promoters for pigs during this stage of growth. Finally, due to extreme variation among and within classifications, there were few significant differences ($P<0.05$) among classifications, although there were wide differences in mean values. The level of variation demonstrated in the lagoons in this study reemphasizes the importance of obtaining individual analysis from each lagoon before land application.

Lagoon Concentration by Season. Seasonal differences in the lagoon samples were determined for a large number of nutrients and other properties. Overall effects of season will be discussed (Table 2) as a uniform pattern was present for all nutrients, regardless of production phase (Tables 3 through 7).

For nitrogen characteristics, the amount of ammonium and total nitrogen concentrations decreased (linear, $P<0.05$) from February until December (Table 2). However, the largest decline occurred between June and August, with a moderate increase from October to December. In addition the concentration of organic nitrogen varied with season (quadratic, $P<0.05$) with the months of December and February having the lowest, while June and August had the highest levels. The decrease in nitrogen during the warmer season can be explained by an increase in activity of bacteria in lagoons during this time, which convert the nitrogen into ammonia that is volatilized.

Phosphorus and phosphate concentrations were influenced (quadratic, $P<0.05$) by season, with the highest levels occurring during June and August, and the lowest during February and December. Also, the concentrations of potassium, potash, and chloride increased (linear, $P<0.05$) during the year. A quadratic effect ($P<0.05$) for all other major (calcium, sodium, magnesium, and sulfur) and minor (copper, zinc, iron, and manganese) nutrients was demonstrated. This response was indicated by an increase in nutrient concentration during warmer months followed by a decrease in the cooler months, except for sodium, which had the opposite response. The concentration of bicarbonate (linear and quadratic, $P<0.05$), percentage solids (quadratic, $P<0.05$), pH (linear, $P<0.05$), and electrical conductivity (linear and quadratic, $P<.05$) was influenced by season.

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The rise in nutrient levels during the summer months may be associated with the increased agitation of solid materials from the lagoon bottom caused by an increase bacteria level associated with warmer temperatures. Furthermore, less rainfall that is typically associated with the summer months may allow the lagoon to become more concentrated with nutrients. These theories would be supported by the fact that the percentage solids were highest during the warmer while lowest in the cooler months in this study.

Hoop Barn Manure Concentrations. All hoop barns sampled in this study housed growing-finishing pigs, therefore, no effects of production phase could be determined. However, seasonal alterations in manure were analyzed (Table 8.)

No seasonal differences (P>0.05) for nitrogen characteristics, phosphorus, potassium, calcium, magnesium, and sulfur were detected (Table 8). However, sodium (linear and quadratic, P<0.05) and chloride (linear, P<0.05) were influenced by season. For trace minerals, zinc and iron were not affected, but copper (quadratic, P<0.05) and manganese (linear, P<0.05) were influenced by season. Percentage solids, pH, and electrical conductivity were not affected by month of sampling.

Nutrient values for hoop barn manure that were determined in this study are the first to be published for Kansas. One striking observation from these results is the higher nutrient concentration associated with hoop barn manure compared to other published values of swine manure with bedding. However, the percentage solids for hoop barn manure is much higher compared to those values (57 vs. 18%), which would contribute to higher nutrient concentrations.

Table 1. Effects of Production Phase on Mean Nutrient Concentration of Kansas Swine Lagoons for 2000[a]

Item	Sow	Nursery	Wean to Finish	Finish	Farrow to Finish	SEM	Overall Mean
Number of samples	50	44	41	56	45		236
Nitrogen, ppm							
Nitrate, NO_3^--N	< 1	< 1	< 1	< 1	< 1	.33	< 1
Ammonium, NH_4^+-N	841^{fg}	1,252^{fg}	1,506^{f}	1,469^{f}	643^{g}	250	1,142
Organic N[b]	125^{h}	312^{fg}	346^{f}	351^{f}	166^{gh}	86	260
Total N	967^{g}	1,563^{fg}	1,852^{f}	1,820^{f}	810^{g}	420	1,402
Major nutrients, ppm							
Phosphorus, P	141^{fg}	223^{fg}	302^{f}	246^{fg}	106^{g}	80	204
Phosphate, P_2O_5[c]	320^{fg}	503^{fg}	686^{f}	559^{fg}	241^{g}	185	462
Potassium, K	856^{g}	1,351^{fg}	1,750^{f}	1,786^{f}	1,125^{fg}	432	1,374
Potash, K_2O[d]	1,030^{g}	1,625^{fg}	2,106^{f}	2,150^{f}	1,354^{fg}	517	1,653
Calcium, Ca	225^{gh}	463^{fg}	465^{fg}	500^{f}	198^{h}	120	370
Sodium, Na	284	282	437	439	281	90	345
Chloride, Cl	509^{h}	647^{fgh}	994^{fg}	1,013^{f}	671^{fgh}	219	767
Magnesium, Mg	30^{h}	89^{fgh}	112^{f}	97^{fg}	43^{gh}	30	74
Sulfur, S	30^{g}	105^{f}	110^{f}	94^{f}	36^{g}	30	75
Copper, Cu	1.0^{g}	6.1^{f}	3.1^{fg}	3.7^{fg}	1.5^{g}	1.6	3.1
Zinc, Zn	3.1^{g}	40.7^{f}	20.2^{g}	16.2^{g}	4.0^{g}	9.7	16.8
Iron, Fe	14.8^{gh}	58.0^{f}	41.0^{fg}	35.4^{fgh}	10.7^{h}	13.9	32.0
Manganese, Mn	1.3^{g}	4.2^{f}	4.4^{f}	4.4^{f}	1.2^{g}	1.3	2.5
Other Constituents							
Carbonate, CO_3	< 1	< 1	< 1	< 1	< 1	.1	< 1
Bicarbonate, HCO_3	4,840^{g}	7,380^{fg}	8,817^{f}	9,199^{f}	4,645^{g}	1,830	6,976
Solids, %	0.5^{g}	1.2^{fg}	1.3^{f}	1.3^{f}	0.6^{g}	.3	1.0
pH	7.8	7.7	7.8	7.8	7.7	.1	7.8
EC[e], mmho cm^{-1}	6.9^{gh}	9.0^{fgh}	9.5^{f}	9.1^{fg}	6.4^{h}	1.3	8.1

[a]A total of 236 samples representing 42 lagoons sampled from February through December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P/0.44). [d]Calculated (K_2O = K/0.83). [e]Electrical Conductivity, mmho cm^{-1}. [fgh]Means in same row with different superscripts differ (P<0.05).

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Table 2. Effects of Season on Nutrient Concentration of Kansas Swine Lagoons for 2000[a]

Item	February	April	June	August	October	December
Number of samples	42	42	41	42	40	29
Nitrogen, ppm						
Nitrate, NO_3^--N	< 1	< 1	< 1	< 1	< 1	< 1
Ammonium, NH_4^+-N[f]	1,348	1,303	1,315	953	894	1,041
Organic N[bg]	223	275	321	286	255	201
Total N[f]	1,571	1,579	1,635	1,239	1,151	1,241
Major Nutrients, ppm						
Phosphorus, P[g]	152	199	287	240	212	131
Phosphate, P_2O_5[cg]	344	453	651	546	482	297
Potassium, K[f]	1,286	1,284	1,353	1,343	1,604	1,370
Potash, K_2O[df]	1,549	1,547	1,624	1,617	1,933	1,649
Calcium, Ca[g]	309	411	390	440	413	258
Sodium, Na[g]	393	305	318	321	391	339
Chloride, Cl[f]	754	647	774	784	891	748
Magnesium, Mg[g]	38	80	102	115	73	39
Sulfur, S[g]	46	85	95	99	77	47
Copper, Cu[g]	1.3	3.2	5.1	4.0	2.8	2.0
Zinc, Zn[g]	8.2	16.8	23.1	26.6	18.5	8.0
Iron, Fe[g]	18.0	30.4	40.9	55.5	34.3	12.9
Manganese, Mn[g]	1.6	3.1	4.7	4.5	3.3	1.4
Other Constituents						
Carbonate, CO_3	< 1	< 1	< 1	< 1	< 1	< 1
Bicarbonate, HCO_3[fg]	7,039	7,013	8,288	6,814	6,460	6,244
Solids, %[g]	0.8	1.0	1.2	1.1	1.1	0.8
pH[f]	7.7	7.5	7.8	7.7	7.9	7.9
EC[efg], mmho cm^{-1}	4.8	8.5	8.9	8.7	10.1	8.2

[a]A total of 236 samples representing 42 lagoons sampled from February through December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P/0.44). [d]Calculated (K_2O = K/0.83). [e]Electrical Conductivity, mmho cm^{-1}. [f]Linear effect, (P<0.05). [g]Quadratic effect, (P<0.05).

Table 3. Effects of Season on Mean Nutrient Concentration of Kansas Sow Lagoons[a]

Item	February	April	June	August	October	December	Mean
Number of samples	9	9	8	9	9	6	50
Nitrogen, ppm							
Nitrate, NO_3^--N	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Ammonium, NH_4^+-N	1,034	1,203	889	639	595	687	841
Organic N[b]	103	149	147	104	139	108	125
Total N	1,137	1,352	1,037	743	747	797	969
Major Nutrients, ppm							
Phosphorus, P	138	139	158	135	196	80	141
Phosphate, P_2O_5[c]	313	316	357	306	445	182	320
Potassium, K	867	861	892	855	951	707	856
Potash, K_2O[d]	1,044	1,037	1,070	1,029	1,146	851	1,030
Calcium, Ca	217	418	183	163	268	100	224
Sodium, Na	348	261	272	254	298	274	285
Chloride, Cl	476	429	524	554	576	497	509
Magnesium, Mg	20	32	34	33	50	13	19
Sulfur, S	23	47	35	22	44	8	30
Copper, Cu	0.3	1.2	2.0	0.5	1.0	1.0	1.0
Zinc, Zn	1.6	3.9	4.2	2.0	6.4	.7	3.1
Iron, Fe	11.6	20.0	23.0	13.4	18.3	2.6	14.8
Manganese, Mn	0.7	1.4	2.4	1.1	2.1	0.4	1.4
Other Constituents							
Carbonate, CO_3	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Bicarbonate, HCO_3	5,337	5,162	5,977	4,405	4,127	4,035	4,841
Solids, %	0.5	0.6	0.6	0.5	0.6	0.3	0.5
pH	7.7	7.6	7.8	7.7	7.9	8.0	7.8
EC[e], mmho cm^{-1}	4.5	7.4	7.6	7.1	7.9	6.7	6.9

[a]Lagoons sampled from February to December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P/0.44). [d]Calculated (K_2O = K/0.83). [e]Electrical Conductivity, mmho cm^{-1}.

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Table 4. Effects of Season on Mean Nutrient Concentration of Kansas Nursery Lagoons[a]

Item	February	April	June	August	October	December	Mean
Number of samples	8	8	8	8	7	5	44
Nitrogen, ppm							
Nitrate, NO_3^--N	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Ammonium, NH_4^+-N	1,356	1,370	1,449	1,143	1,117	1,077	1,252
Organic N[b]	226	307	342	520	294	186	312
Total N	1,582	1,676	1,791	1,664	1,409	1,257	1,563
Major Nutrients, ppm							
Phosphorus, P	145	217	257	396	250	67	223
Phosphate, P_2O_5[c]	328	492	582	899	569	151	503
Potassium, K	1,233	1,328	1,369	1,282	1,550	1,315	1,351
Potash, K_2O[d]	1,486	1,599	1,675	1,544	1,867	1,582	1,625
Calcium, Ca	317	410	431	875	562	183	463
Sodium, Na	328	262	257	263	308	274	282
Chloride, Cl	561	554	662	741	706	656	647
Magnesium, Mg	43	90	82	212	94	15	89
Sulfur, S	54	123	117	213	106	16	105
Copper, Cu	2.4	6.5	7.8	9.9	6.6	3.2	6.1
Zinc, Zn	16.2	41.0	41.5	85.7	51.1	8.9	40.7
Iron, Fe	22.0	50.0	54.7	152.5	59.8	9.1	58.0
Manganese, Mn	1.5	3.7	4.7	10.6	4.5	0.6	1.3
Other Constituents							
Carbonate, CO_3	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Bicarbonate, HCO_3	6,873	7,618	8,911	7,761	7,141	5,979	7,380
Solids, %	0.8	1.2	1.2	1.8	1.3	0.7	1.2
pH	7.5	7.4	7.8	7.8	7.9	7.9	7.7
EC[e], mmho cm^{-1}	4.8	9.5	9.8	9.2	11.0	9.6	9.0

[a]Lagoons sampled from February to December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P/0.44). [d]Calculated (K_2O = K/0.83). [e]Electrical Conductivity, mmho cm^{-1}.

Table 5. Effects of Season on Mean Nutrient Concentration of Kansas Wean-to-Finish Lagoons[a]

Item	February	April	June	August	October	December	Mean
Number of samples	7	7	7	7	7	6	41
Nitrogen, ppm							
Nitrate, NO_3^--N	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Ammonium, NH_4^+-N	1,740	1,625	1,735	1,137	1,452	1,350	1,506
Organic N[b]	304	327	441	317	493	190	346
Total N	2,004	1,952	2,175	1,455	1,945	1,543	1,852
Major Nutrient, ppm							
Phosphorus, P	205	271	452	299	384	200	302
Phosphate, P_2O_5[c]	466	616	1,026	1,680	874	454	686
Potassium, K	1,513	1,575	1,703	1,688	2,152	1,866	1,750
Potash, K_2O[d]	1,823	1,898	2,043	2,033	2,592	2,245	2,106
Calcium, Ca	352	523	443	441	673	357	465
Sodium, Na	466	391	404	404	514	442	437
Chloride, Cl	954	845	1,012	949	1,234	968	994
Magnesium, Mg	51	133	166	143	123	57	112
Sulfur, S	68	103	140	115	137	99	110
Copper, Cu	1.4	3.0	3.9	3.4	4.1	2.5	3.1
Zinc, Zn	12.0	19.7	21.9	26.2	24.7	17.0	20.2
Iron, Fe	28.1	38.4	43.7	56.3	56.4	24.3	41.0
Manganese, Mn	2.4	4.5	6.0	5.0	6.2	2.4	4.4
Other Constituents							
Carbonate, CO_3	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Bicarbonate, HCO_3	8,578	8,732	10,607	7,973	9,576	7,440	8,817
Solids, %	1.0	1.2	1.6	1.3	1.7	1.2	1.3
pH	7.6	7.5	7.9	7.7	7.9	7.8	7.8
EC[e], mmho cm^{-1}	5.5	10.5	10.1	9.9	12.4	9.0	9.5

[a]Lagoons sampled from February to December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P/0.44). [d]Calculated (K_2O = K/0.83). [e]Electrical Conductivity, mmho cm^{-1}.

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Table 6. Effects of Season on Mean Nutrient Concentration of Kansas Finishing Lagoons[a]

Item	February	April	June	August	October	December	Mean
Number of samples	10	10	10	10	9	7	56
Nitrogen, ppm							
Nitrate, NO_3^--N	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Ammonium, NH_4^+-N	1,850	1,543	1,770	1,342	816	1,495	1,469
Organic N[b]	353	384	437	363	209	362	351
Total N	2,202	1,927	2,206	1,706	1,023	1,859	1,820
Major Nutrients, ppm							
Phosphorus, P	185	284	403	247	122	238	246
Phosphate, P_2O_5[c]	420	644	914	560	278	538	559
Potassium, K	1,790	1,700	1,753	1,651	1,949	1,877	1,786
Potash, K_2O[d]	2,156	2,048	2,103	1,987	2,348	2,259	2,150
Calcium, Ca	441	512	615	548	382	500	500
Sodium, Na	513	366	413	399	490	452	439
Chloride, Cl	1,053	909	1,038	954	1,094	1,033	1,013
Magnesium, Mg	48	106	168	125	57	77	97
Sulfur, S	70	103	130	108	61	95	94
Copper, Cu	1.8	3.5	7.0	4.8	2.0	3.0	3.7
Zinc, Zn	8.6	15.4	38.1	15.2	7.6	12.5	16.2
Iron, Fe	22.6	36.7	60.0	41.2	26.2	25.9	35.4
Manganese, Mn	2.6	5.0	7.2	5.0	3.0	3.7	4.4
Other Constituents							
Carbonate, CO_3	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Bicarbonate, HCO_3	9,597	9,148	10,862	9,514	6,810	9,265	9,199
Solids, %	1.2	1.4	1.7	1.3	1.0	1.3	1.3
pH	7.7	7.6	7.8	7.8	7.9	7.9	7.8
EC[e], mmho cm^{-1}	5.3	9.2	9.9	10.2	11.1	9.4	9.1

[a]Lagoons sampled from February to December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P / .44). [d]Calculated (K_2O = K / .83). [e]Electrical Conductivity, mmho cm^{-1}.

Table 7. Effects of Season on Mean Nutrient Concentration of Kansas Farrow-to-Finish Lagoons[a]

Item	February	April	June	August	October	December	Mean
Number of samples	8	8	8	8	8	5	45
Nitrogen, ppm							
Nitrate, NO_3^--N	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Ammonium, NH_4^+-N	764	779	731	505	488	594	643
Organic N[b]	127	208	240	125	138	157	166
Total N	891	987	970	630	630	753	810
Major Nutrients, ppm							
Phosphorus, P	86	87	165	123	106	72	106
Phosphate, P_2O_5[c]	194	197	375	279	241	162	241
Potassium, K	1,024	957	1,023	1,238	1,422	1,086	1,125
Potash, K_2O[d]	1,234	1,153	1,228	1,490	1,713	1,308	1,354
Calcium, Ca	216	193	280	172	182	150	198
Sodium, Na	311	246	246	287	345	256	281
Chloride, Cl	726	499	639	721	850	590	671
Magnesium, Mg	30	37	58	61	40	30	43
Sulfur, S	18	49	53	39	41	20	36
Copper, Cu	0.5	1.8	4.8	1.2	0.5	0.2	1.5
Zinc, Zn	2.5	4.1	9.8	3.8	2.7	0.8	4.0
Iron, Fe	6.0	7.0	23.9	14.2	10.7	2.8	10.7
Manganese, Mn	0.6	1.1	3.3	1.1	1.0	0.4	1.2
Other Constituents							
Carbonate, CO_3	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Bicarbonate, HCO_3	4,813	4,402	5,085	4,421	4,648	4,504	4,645
Solids, %	0.5	0.6	0.8	0.7	0.7	0.6	0.6
pH	7.7	7.7	7.7	7.7	7.9	7.8	7.7
EC[e], mmho cm^{-1}	3.9	5.8	7.2	7.2	8.1	6.4	6.4

[a]Lagoons sampled from February to December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P/0.44). [d]Calculated (K_2O = K/0.83). [e]Electrical Conductivity, mmho cm^{-1}.

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Table 8. Effects of Season on Mean Nutrient Concentration of Kansas Hoop Barn Manure[a]

Item	February	April	June	August	October	December	SEM	Mean
Number of samples	6	6	6	6	6	5		35
Nitrogen, ppm								
Nitrate, NO_3^--N	238	159	191	N/A	678	81	173	225
Ammonium, NH_4^+-N	1,695	2,067	1,706	1,634	2,315	2,601	518	2,003
Organic N[b]	6,078	6,075	8,155	7,131	4,910	6,238	896	6,431
Total N	7,850	8,377	10,128	8,841	7,904	8,966	1,177	8,678
Major Nutrients, ppm								
Phosphorus, P	4,194	3,677	3,786	4,963	4,710	4,851	645	4,364
Phosphate, P_2O_5[c]	9,532	8,357	8,595	11,265	10,703	11,003	1,467	9,908
Potassium, K	7,835	8,426	8,662	8,131	9,534	10,616	1,184	8,867
Potash, K_2O[d]	9,439	10,152	10,392	9,789	11,486	12,778	1,425	10,673
Calcium, Ca	46,279	29,764	36,569	36,625	52,254	60,564	10,554	43,676
Sodium, Na[fg]	2,117	1,248	1,225	1,096	1,347	1,361	235	1,398
Chloride, Cl[f]	2,123	2,134	1,208	2,798	3,096	3,215	376	2,429
Magnesium, Mg	3,315	2,669	2,886	3,323	3,428	3,639	325	3,210
Sulfur, S	1,491	1,674	1,854	1,268	1,607	1,490	230	1,564
Copper, Cu[g]	81	75	575	38	29	40	54	140
Zinc, Zn	157	177	157	215	159	220	31	181
Iron, Fe	4,128	5,635	2,873	5,129	5,087	6,544	1,243	4,899
Manganese, Mn[f]	196	219	216	232	265	289	39	236
Other Constituents								
Solids, %	51	55	60	47	57	69	6	57
pH	7.1	7.0	7.1	N/A	6.7	7.0	.3	7.0
EC[e], mmho cm^{-1}	5.4	7.2	7.1	N/A	9.5	6.1	.6	7.1

[a]Lagoons sampled from February to December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P/0.44). [d]Calculated (K_2O = K/0.83). [e]Electrical Conductivity, mmho cm^{-1}. [f]Linear effect, $P<0.05$. [g]Quadratic effect, $P<0.05$.

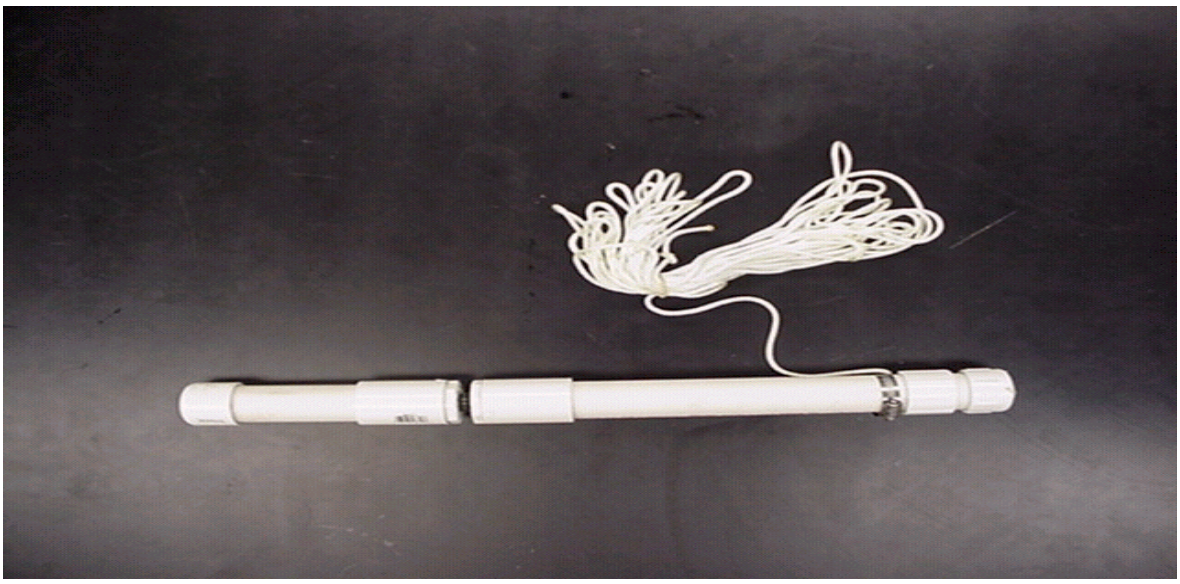

Figure 1. Lagoon Sampler.

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COMPARISON OF BIOAEROSOL SAMPLING METHODS FOR SWINE BARNS [1]

B. Z. Predicala [2], J. E. Urban [3], R. G. Maghirang [2], S. B. Jerez [2], and R. D. Goodband

Summary

Two bioaerosol sampling methods (Andersen sampler and filtration sampler) were compared. The two samplers were used to assess the bioaerosol loads in two swine finishing barns. They were similar in terms of the species of microorganisms sampled. The persistent strains of microorganisms were various species of the following genera: *Staphylococcus, Pseudomonas, Bacillus, Listeria, Enterococcus, Nocardia, Lactobacillus,* and *Penicillium*. However, the use of Andersen sampler resulted in significantly higher bioaerosol concentrations than the filtration sampler. Thus, it appears that filtration sampling can be used for a qualitative survey of bioaerosols in swine barns while the Andersen sampler is suitable for both quantitative and qualitative assessments.

(Key Words: Airborne Microorganisms, Bioaerosol Sampling, Swine Housing.)

Introduction

Bioaerosols include airborne particles that are living, as well as large molecules and volatile compounds that were released from a living organism. Previous studies have documented considerably higher bioaerosol concentrations in animal houses than in industrial, residential or ambient settings. Inhalation of bioaerosols can be detrimental to health through infection, allergy or toxicosis. Thus, there is a need to assess potential health risks by measuring work-place exposure to bioaerosols.

Various bioaerosol assessment methods have been reviewed and the characteristics of the different bioaerosol sampling devices have also been evaluated. However, standard methods for bioaerosol assessment have not been established and no bioaerosol sampler has been fully characterized in terms of its physical and biological sampling efficiencies. In the absence of standard methods, existing methods should be validated.

Impaction and filtration are used widely for assessing the airborne microbial loads inside livestock buildings. The six-stage Andersen viable cascade impactor (herein referred to as Andersen sampler) is the most commonly used bioaerosol sampler; it has served as a reference sampler in evaluating other sampling devices. Filtration sampling, on the other hand, is simple and relatively inexpensive compared to other sampling methods. In addition, filters can be assayed by a variety of culture and non-culture methods.

The main objective of the study was to compare bioaerosol sampling by filtration and impaction (i.e., Andersen sampler). The information will be useful to producers and

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researchers in determining appropriate sampling methods for livestock buildings.

Procedures

Bioaerosol concentrations were measured in two swine finishing barns weekly from November 1999 to June 2000. The barns, one naturally ventilated and one mechanically ventilated, were located on the same commercial swine farm in northeast Kansas. They were similar in terms of outdoor environmental conditions, breed of pigs, type of feeds and supplements, feeding system, veterinary support, and husbandry practices. In addition, both barns had slatted floors, automatic self-feeders, and drinkers. Ground feed from bins outside the barns was distributed through overhead augers to the feeders. Both barns had gas heaters that provided supplemental heat during extremely cold weather, as well as water misting systems for cooling during hot weather.

The naturally ventilated barn (450 ft long, 40 ft wide) had five rooms that were separated from each other by solid partitions from floor to roof. The waste management system consisted of collecting the manure in shallow underfloor pits and flushing the pits twice a week. Environmental conditions inside the barn were regulated by automatically raising or lowering the curtains on either side of the barn, manually adjusting the ridge slot opening, and/or operating the misting system or supplemental heater mentioned above.

The mechanically ventilated barn (175 ft long, 32 ft wide) had two rooms separated by a solid wall and a curtain over a central alley. Ventilation air entered through slot inlets along the top of the side walls and was exhausted by two 3-ft diameter wall fans. The fans were operated intermittently by an electronic thermal controller system. Manure was collected in static pits about 4 ft deep; a submerged stand pipe maintained the manure slurry depth at 3 ft by draining the overflow into the pipe to a nearby lagoon. In each room, two fans with a diameter of 2 ft provided pit ventilation.

The mean stocking densities were 7.3 and 7.0 ft^2/head in the naturally and mechanically ventilated barns, respectively. The pigs were brought into the barns when they weighed about 50 to 75 lb each and remained in the barns for about 15 to 17 weeks, until they reached a marketing weight of about 240 to 275 lb.

The air temperatures inside the barns ranged from 58 to 90°F with a slightly lower mean for the naturally ventilated barn at 71°F (SD = 10°F) compared to the mechanically ventillated barn at 76°F (SD = 7/F). The relative humidity (RH) inside the barns ranged from 26 to 61% with a mean of 40% (SD = 11%). The outside air temperatures for the duration of the study (obtained from the nearest weather station) ranged from 28 to 80°F with a mean of 48/F (SD = 15°F), and the outside RHs ranged from 37 to 90%, with a mean of 66% (SD = 18%).

Two bioaerosol sampling methods were used: filtration and impaction. Filtration involved collection of airborne particulates on sterilized cellulose nitrate membrane filters and incubation on plates with R2A agar as culture medium. Air was sampled at a flow rate of 2.0 L/min for 3 minutes. An open-faced filter holder loaded with a 47-mm membrane filter and a 37-mm membrane filter with a respirable dust cyclone preseparator were used for sampling total and respirable bioaerosols, respectively. The cyclone had a 50% cut-point of 4.0 μm aerodynamic diameter. Duplicate samples were obtained inside each barn along the alley; one sample was taken about 5 m upwind outside each barn to determine the background concentration.

Sampling by impaction was done with the Andersen sampler. The sampler was a cascade impactor with 400 holes per stage and was able to separate the particles into the following size ranges: >7, 4.7-7, 3.3-4.7, 2.1-3.3, 1.1-2.1, and 0.65-1.1 μm. It was operated with a Petri dish with R2A agar under each stage. Duplicate samples were collected inside each barn along the alley at an airflow rate of 28.3 L/min for 1 min.

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All culture plates were incubated at room temperature (77°F ± 9°F) for 72 h. After incubation, the colony forming units (CFUs) were counted with a colony counter. The colonies on each plate also were categorized based on appearance (i.e., color, surface form, size and surface texture). The commonly encountered strains were isolated and pure cultures of each were preserved on R2A agar stock slants. The stock strains were Gram stained and the species determined whenever possible by inoculating them on different types of selective and differential media (MacConkey, Phenethyl Alcohol Agar, Kligler's Iron Agar, Lysine Iron Agar, Sheep blood agar), which were examined according to the medium protocol.

Bioaerosol concentrations were obtained by dividing the number of CFUs by the volume of air sampled (6 L for the filter sampler and 28.3 L for the Andersen sampler). For the Andersen sampler, the total bioaerosol concentration was the sum of CFU concentrations in all six stages while the respirable fraction was taken as the sum of CFU concentrations in stages 3 to 6 (<4.7 μm aerodynamic diameter). Paired t-tests on the CFU concentrations to compare the two barns and the two sampling methods were conducted using PC-SAS.

Results and Discussion

In the 2000 Swine Day Report of Progress (p 114) we reported total CFU and respirable CFU values for both the mechanically and naturally ventilated barns. Since that publication, we have continued to monitor these criteria. However, the values remain similar to those collected last year. The total CFU concentration in the NV barn obtained by the filter sampler ranged from 1.2×10^4 to 2.4×10^5 CFU/m^3 with a mean of 5.8×10^4 CFU/m^3. Corresponding values in the mechanically ventilated barn ranged from 1.3×10^4 to 1.4×10^5 CFU/m^3 with a mean of 6.5×10^4 CFU/m^3. The respirable CFU concentration in the NV barn ranged from 5.0×10^2 to 4.5×10^4 CFU/m^3 with a mean of 1.0×10^4 CFU/m^3 and the corresponding values in the mechanically ventilated barn ranged from 1.6×10^3 to 6.4×10^4 with a mean of 1.1×10^4 CFU/m^3. The respirable fraction was about 20% (SD = 19.9%) of the total CFU concentration in the naturally ventilated barn and about 18% (SD = 11.9%) in the mechanically ventilated barn. The two barns did not show any significant difference ($P>0.05$) in total and respirable CFU concentrations obtained by filtration.

Similar trends were observed in the total and respirable CFU concentrations in the naturally ventilated and mechanically ventilated barns measured by the Andersen sampler, although the actual concentrations were higher compared to those obtained by filtration. Thus, for both the filter and Andersen samplers the corresponding data from the two barns were combined in subsequent analyses.

The total CFU concentrations inside the barns measured by filtration were about 3.6 times (range = 0.5 to 11.0) the outside concentrations while the inside respirable values were about 2.9 times (range = 0.1 to 9.5) the outside concentrations. This was expected because the main sources of bioaerosols were inside the barns. The measured concentrations were within the range of published values from similar studies in swine buildings.

Comparison of the two samplers showed significant differences ($P<0.05$) in the total and respirable CFU concentrations (Table 1). Filtration had significantly ($P<0.05$) lower (by about 23%) total CFU concentration compared to the Andersen sampler. This could be attributed to the possible desiccation of the microorganisms on the membrane filter during sampling.

The filter sampler with the cyclone preseparator also had significantly ($P<0.05$) lower respirable CFU concentration compared to the Andersen sampler (Table 1). The large disparity in the respirable fraction between the two sampling methods (about 68% in terms of respirable CFU concentration) could be explained by several factors such as the possible desiccation associated with filtration, slightly lower cut-off diameter of the cyclone preseparator (4.0 μm) compared to that of the Andersen sampler

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(4.7 μm), and possible wall losses in the cyclone.

Identification of the persistent strains of microorganisms showed that *Staphylococcus* accounted for over 70% of the total CFUs for both sampling methods. The other predominant types of organisms were *Pseudomonas, Bacillus, Listeria, Enterococcus, Nocardia, Lactobacillus*, and *Penicillium*.

Most of the above organisms were observed in all six stages of the Andersen sampler, although in varying proportions. This could indicate that cells or spores of specific microorganisms may have been aerosolized in different sizes or may be attached to particles of various sizes, thus they were deposited in all of the stages of the sampler. Of the various genera identified, *Staphylococcus* and *Lactobacillus* occurred mainly in the top three stages (>3.3 mm), while *Enterococcus*, *Bacillus*, and *Nocardia* appeared almost in uniform percentages throughout all stages, indicating wide variability in particle size. The concentrations of *Penicillium, Pseudomonas* and *Listeria* were higher in stages 3 (size range = 3.3 to 4.7 mm) and 4 (2.1 to 3.3 mm).

Comparison of the filter and Andersen samplers for each of the eight types of organisms showed that they differed significantly ($P<0.05$) in two (*Staphylococcus* and *Pseudomonas*) out of the eight strains in terms of total concentrations and four strains (*Staphylococcus, Bacillus, Listeria, Enterococcus*) in terms of respirable concentration.

From these observations, it appears that filtration sampling combined with the appropriate culture medium and sampling protocol can be used to assess qualitatively the bioaerosols in swine buildings. For both quantitative and qualitative assessments, the Andersen sampler can be used.

Table 1. Total and Respirable CFU Concentrations Inside the Two Swine Barns Using Filtration and Impaction Sampling Methods, CFU/m^3 (n = 22)

	Filtration			Impaction		
	Total	Respirable	Respirable Percentage[a]	Total	Respirable	Respirable Percentage
Mean	6.6×10^{4} [b]	9.0×10^{3} [b]	15.6% [b]	8.6×10^{4}	2.8×10^{4}	31.6%
SD	3.8×10^{4}	4.1×10^{3}	8.0%	5.1×10^{4}	2.2×10^{4}	9.0%

[a]Respirable percentage = (respirable concentration/total concentration) × 100.
[b]Indicates significant difference ($P<0.05$) compared to corresponding mean for impaction.

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UTILIZING INFRARED THERMOGRAPHY TO PREDICT PORK QUALITY

T. E. Lawrence, M. F. Spire [1], M. E. Dikeman, M. C. Hunt, S. B. Hogge [1], and B. W. James

Summary

Three experiments using 63 pigs were conducted to determine if infrared thermography could segregate pigs based on subsequent pork quality. Pigs were subjectively classified as either "hot" or "normal" based on infrared surface temperature of the loin region prior to slaughter. In the first experiment 18 market weight pigs were transported, imaged by infrared thermography and slaughtered immediately after 1 to 4 h of lairage. Differences in meat quality were detected; hot pigs had lower a* (less red) and chroma (less intense red color) values, and higher hue angle (less red/more yellow) values, all of which indicate paler muscle color. In the second experiment, 27 market weight pigs were transported, held in lairage for 12 to 16 h, imaged by infrared thermography, and then slaughtered. In the third experiment, 18 market weight pigs were transported, imaged by infrared thermography, held in lairage for 12 to 16 h, and then slaughtered. Regardless of the time infrared images were taken, no meat quality differences between hot and normal pigs were detected when pigs were held in lairage for 12 to 16 h. These data suggest that measurement of live animal surface temperature by infrared thermography may allow for detection of poor meat quality if pigs are slaughtered without extended lairage.

(Key Words: Infrared Thermography, Pork Quality.)

Introduction

Ten to 16% of the U.S. pork supply has PSE (pale, soft, and exudative) meat characteristics. Estimates of unrealized revenue due to the PSE meat condition total $275 million annually for the U.S. pork industry. Currently, methods for identifying individuals or groups of pigs likely to result in PSE meat quality are not in commercial use. If a method was utilized prior to slaughter, intervention strategies could be put in place to reduce the risk or prevalence of PSE carcasses. A proposed method is infrared thermography (IRT). Infrared thermography is a rapid, non-invasive procedure used to measure the surface temperature of an object without having any physical contact to the object. Previous scientific literature concerning the relationship between IRT and PSE meat suggest that pigs with surface temperatures warmer than normal are likely to yield carcasses with pale muscle color and higher moisture losses. The objective of this research was to determine if infrared thermography could segregate live pigs based on subsequent muscle quality.

Procedures

Surface temperatures of 63 market pigs slaughtered in three groups were collected using a short-wave infrared radiometer (PM 280 Thermacam, Inframetrics, N. Billerica, MA) prior to slaughter at the KSU Meat Laboratory. Subjective infrared temperature determination of "hot" (pigs with thermal images in the top 1.5°C of the temperature spectrum) or "normal" was made for each

[1]Food Animal Health and Management Center.

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pig in the loin region from the shoulder to the hips. In the first experiment, pigs (n=18) were transported from the KSU swine farm to the meat laboratory, scanned by infrared thermography and then slaughtered immediately after 1 to 4 h lairage. For the second experiment, pigs (n=27) were transported from the KSU swine farm to the meat laboratory, held in lairage overnight for 12 to 16 h, scanned by infrared thermography and then slaughtered. For the third experiment, pigs (n=18) were transported from the KSU swine farm to the meat laboratory, scanned by infrared thermography, held in lairage overnight for 12 to 16 h, then slaughtered. At 45 min postmortem, 10th rib longissimus muscle pH and temperature was measured with a portable meter (Accumet AP61, Fisher Scientific, Pittsburgh, PA). At 24 h postmortem after a 30 min bloom, 10th rib loin chops were evaluated for visual (NPPC) and instrumental color (L*, a*, b*; 10^o observer, Illuminant C; HunterLab Miniscan, Hunter and Associates, Reston, VA), firmness (NPPC), marbling (estimated percentage of intramuscular fat; NPPC), drip loss (fishhook method), and ultimate (24 h) pH. Chroma ($C^*_{ab} = \{a^{*2} + b^{*2}\}^{1/2}$) and hue angle ($h_{ab} = \arctan\{b^*/a^*\}$ also were calculated.

For each experiment, data for this observational study were analyzed as one-way treatment structure in an unbalanced completely randomized design. Individual pigs were the experimental units.

Results and Discussion

Significant differences in a* values were detected between hot and normal pigs from experiment 1 (Table 1). Hot pigs had lower (P=0.01) a* (less red) values than normal pigs. In addition, hot pigs tended (P=0.07) to have lower b* (less yellow) values than normal pigs. Moreover, hot pigs had lower (P=0.02) chroma (less intense red color) and higher (P=0.04) hue angle (less red/more yellow) values than normal pigs. These data are consistent with previous literature in that lower a* and chroma values as well as higher hue angle indicate pale muscle color, a key trait of PSE meat. In contrast, previous literature would indicate that PSE pork should have higher b* values than normal pork. No differences between hot and normal pigs were detected for 45 min or 24 h pH, 45 min temperature, visual color scores, L* (lightness), firmness, marbling, and percentage of drip loss.

Pigs for experiment 2 and 3 were held in lairage overnight for 12 to 16 h before slaughter. No differences in any pork quality measurements were detected when pigs were scanned after lairage (Experiment 2, Table 2) or prior to lairage (Experiment 3, Table 3). It appears that after a 12 h lairage period meat quality was improved such that differences were not detectable by infrared thermography. Normal lairage conditions in commercial pork processing systems are 2 to 4 h. A 12 to 16 h lairage is considerably longer than most commercial processors and likely caused those pigs to exhaust their stored glycogen supply antemortem, thereby improving meat quality.

Infrared thermography is a rapid, non-invasive, easy-to-use technique that may allow for the detection of poor meat quality ante-mortem. Our results suggest that infrared thermography may allow for detection of poor meat quality if animals are imaged and then slaughtered immediately without extended lairage. Our findings also suggest that infrared thermography is not useful in detecting poor meat quality if pigs are allowed to rest for 12 to 16 h before slaughter. Once a pig or group of pigs that exceeds a surface temperature threshold has been identified, intervention strategies known to improve muscle quality can be put in action to reduce the incidence of the PSE meat condition. Those strategies may include increased lairage time, water shower or pool cooling, and fan cooling. When used successfully, this strategy should reduce the percentage of PSE carcasses; thereby increasing the value of numerous carcasses and minimizing lost revenue.

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Table 1. Variation in Pork Longissimus Muscle Quality from Pigs Transported, Imaged by Infrared Thermography and then Slaughtered Immediately after 1 to 4 h of Lairage (Experiment 1)

Item	"Hot" Pigs [a]	"Normal" Pigs	P- Value	SE
Number	4	14		
45 min pH	6.50	6.32	.16	.12
24 h pH	5.80	5.77	.63	.06
45 min temperature	35.05	34.88	.89	1.23
Visual color [b]	2.75	3.11	.19	.26
L* (lightness)	56.76	56.06	.57	1.20
a* (redness)	5.05	6.81	.01	.58
b* (yellowness)	13.80	14.95	.07	.59
Chroma	14.75	16.44	.02	.63
Hue angle	69.87	65.44	.04	1.96
Firmness [c]	2.38	2.14	.42	.28
Estimated percentage intramuscular fat	1.38	1.71	.22	.27
Drip loss, %	1.75	2.43	.34	.69

[a]Pigs with infrared thermographs in the top 1.5°C of the temperature spectrum.
[b]1.0 = pale pinkish gray to white, 2.0 = grayish pink, 3.0 = reddish pink, 4.0 = dark reddish pink, 5.0 = purplish red, 6.0 = dark purplish red.
[c]1.0 = soft, 2.0 = firm, 3.0 = very firm.

Table 2. Variation in Pork Longissimus Muscle Quality from Pigs Transported, Held in Lairage for 12 to 16 h, Imaged by Infrared Thermography and then Slaughtered (Experiment 2)

Item	"Hot" Pigs [a]	"Normal" Pigs	P - Value	SE
Number	4	23		
45 min pH	6.15	6.35	.19	.15
24 h pH	5.76	5.74	.75	.04
45 min temperature	35.18	34.99	.85	.97
Visual color [b]	2.88	3.04	.65	.36
L* (lightness)	59.62	59.24	.86	2.12
a* (redness)	6.30	6.04	.67	.59
b* (yellowness)	15.12	14.97	.84	.75
Chroma	16.39	16.16	.79	.83
Hue angle	67.19	68.03	.61	1.66
Firmness [c]	1.13	1.39	.37	.29
Estimated percentage intramuscular fat	2.13	2.35	.41	.26
Drip loss, %	2.59	2.34	.79	.93

[a]Pigs with infrared thermographs in the top 1.5°C of the temperature spectrum.
[b]1.0 = pale pinkish gray to white, 2.0 = grayish pink, 3.0 = reddish pink, 4.0 = dark reddish pink, 5.0 = purplish red, 6.0 = dark purplish red.
[c]1.0 = soft, 2.0 = firm, 3.0 = very firm.

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Table 3. Variation in Pork Longissimus Muscle Quality from Pigs Transported, Imaged by Infrared Thermography, Held in Lairage for 12 to 16 h and then Slaughtered (Experiment 3)

Item	"Hot" Pigs [a]	"Normal" Pigs	P - Value	SE
Number	3	14		
45 min pH	6.48	6.45	.80	.11
24 h pH	5.85	5.83	.71	.06
45 min temperature	32.23	33.28	.35	1.08
Visual color [b]	3.17	2.90	.51	.40
L* (lightness)	55.57	58.37	.22	2.17
a* (redness)	6.57	7.03	.61	.90
b* (yellowness)	14.99	15.43	.59	.79
Chroma	16.38	16.99	.52	.95
Hue angle	66.37	65.57	.76	2.57
Firmness [c]	2.00	2.17	.60	.31
Estimated percentage intramuscular fat	1.17	1.43	.39	.30
Drip loss, %	2.47	2.93	.66	.46

[a]Pigs with infrared thermographs in the top 1.5°C of the temperature spectrum.
[b]1.0 = pale pinkish gray to white, 2.0 = grayish pink, 3.0 = reddish pink, 4.0 = dark reddish pink, 5.0 = purplish red, 6.0 = dark purplish red.
[c]1.0 = soft, 2.0 = firm, 3.0 = very firm.

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INFLUENCE OF DIFFERENT EQUIPMENT PROTOCOLS ON PARTICLE SIZE DETERMINATION OF GROUND CORN

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

Summary

Two experiments were conducted to determine the influence of the tapping bar and sieve agitators (balls and brushes) on determining mean particle size and standard deviation of ground corn. Tapping bar had no influence ($P>0.10$) on mean and standard deviation; however the presence of balls and brushes on sieves decreased ($P<0.002$) mean particle size and increased ($P<0.0001$) standard deviation. These results suggest that balls and brushes should be used when determining mean particle size to assist particle flowability. More research should be conducted to determine the effects of the tapping bar and sieve agitators over a wider range of particle sizes.

(Key Words: Particle Size, Tapping Bar, Sieve Agitators.)

Introduction

Determining particle size of ground grains is an important part of the quality control program for feed mills and swine producers alike. For feed mills, coarse ground grain is associated with poor mixing characteristics, whereas grinding grain too fine results in greater energy consumption and lower production rates. For swine producers, poorer digestibilities and growth performance are associated with coarse ground grain and poorer feed flowability, increased dustiness, and the development of ulcers are problems associated with feeding grains that are ground too fine. Thus, proper determination of particle size of ground grains will have huge financial impacts for both feed mills and swine producers.

The approved method for determining particle size was outlined in the ASAE publication S319. Since its publication in 1968, different types of equipment to determine particle size have been created and modifications to the original protocol have occurred. The original publication suggests that sieve agitators be used to separate particles on smaller sieves; however, no one has evaluated the influence of these agitators (balls and brushes) on mean and standard deviation determination. The objective of these experiments was to measure the influence of different equipment protocols on the determination of particle size of ground corn.

Procedures

General. Ground corn was used to measure the influence of different equipment protocols on the determination of particle size. Twenty pounds of whole kernel corn was obtained from the Kansas State University Animal Science Feed Mill. The corn was ground to two different particle sizes. Each particle size was then sub-sampled into twenty 200-g aliquots that were passed through a riffle splitter to form two similar 100-g samples. Each of the 100-g samples was then randomly allotted to one of two treatments for Exp. 1 (balls and brushes vs. no balls and brushes) and Exp. 2 (tapping bar vs. no tapping bar). There were 10 replications of each particle size within each treatment for both experiments.

[1]Food Animal Health and Management Center.

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The basic standard operating procedures used at Kansas State University were followed for these experiments. Briefly, 100-g of sample was placed on the top of the sieve stack. The sieve stack contained 13 individual sieves with openings ranging from 3,350 to 53 microns (Table 1). The stack was then placed in the Ro-tap brand shaker machine (W. S. Tyler, Mentor, OH) and shaken for 10 minutes. The machine used at Kansas State University utilizes a tapping bar and shakes the samples at 1,725 rpm. One to 3 balls and/or brushes are placed on top of some sieves as illustrated in Figure 1. Weight of sample remaining on each sieve after the 10 minutes is then used to determine mean particle size and standard deviation.

Experiment 1. The influence of sieves with or without balls and brushes was evaluated. The approved 13-high sieve stack and general standard operating procedure were used. Sieves contained either no balls or brushes or 1 to 3 balls and/or brushes as indicated in Table 1. The tapping bar was used for both treatments.

Experiment 2. The influence of tapping bar was determined in Exp. 2 with samples allotted to either tapping or no tapping bar treatments. Standard operating procedures were used for the tapping bar treatment and the bar was removed for the no tapping bar treatment. Balls and brushes were included on the sieves as described for Exp. 1.

Statistics. Both experiments were analyzed as a completely randomized design with sample as the experimental unit. Paired T-tests were used to compare means of the experimental treatments.

Results and Discussion

For Exp. 1, the presence of balls and brushes reduced ($P<0.002$; Table 2) mean particle size and increased standard deviation compared to samples analyzed without the balls and brushes. For Exp. 2, no differences ($P>0.10$; Table 3) were observed when the tapping bar was removed from the sieve stack for either mean particle size or standard deviation.

These results indicate that the tapping bar did not influence mean particle size or standard deviation of the ground corn samples used in our study (approximately 430 and 650 microns). However, the tapping bar may have an influence on samples that have a mean particle size outside of the range tested in this experiment. Also, mean particle size of samples that tend to be more adherent (higher moisture grains, high-oil varieties, complete diets, etc.) may be influenced by the presence of the tapping bar. More research should be conducted to determine the influence of the tapping bar on mean particle size of a wider range of feedstuffs. Sieve agitators, such as the balls and brushes, influenced both mean and standard deviation of the samples we analyzed. When the balls and brushes were used, mean particle size decreased and standard deviation increased suggesting that the sample was able to pass through the sieves more efficiently than when no balls or brushes were included. The purpose of the balls and brushes is to keep the sieve surface from becoming blocked by particles that can not pass through the openings. They will not break particles to smaller sizes or force particles through the sieve. Different configurations of balls and brushes would also be expected to influence the results, but were not tested in these experiments. Shaker machines that rotate at speeds other than 1,725 rpm are available, and would be expected to influence determination of mean particle size and standard deviation. Unfortunately, we were not able to evaluate the influence of rotation speed on mean particle size and standard deviation.

In conclusion, the tapping bar had no effect on mean particle size or standard deviation of samples tested in this experiment. Sieve agitators such as the balls and brushes used in these experiments should be used when determining mean particle size to assist particle flowability through the sieves. This experiment illustrates the importance of consistently using the correct procedure to determine mean particle size and standard deviation. More research should be conducted to determine the influence of sieve agitators and the tapping bar over a wider range of mean particle sizes and with a greater variety of feedstuffs.

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Figure 1. Ro-tap Shaker Machine with Sieve Stack.

Figure 2. Ball and Brush Resting of a Sieve.

Table 1. Sieve Stack and Number of Balls and/or Brushes Included on Each Sieve

Sieve number, US	Opening, microns	Balls, number	Brushes, number
6	3,350	-	-
8	2,360	-	-
12	1,700	3	-
16	1,180	3	-
20	850	3	-
30	600	1	1
40	425	1	1
50	300	1	1
70	212	1	1
100	150	-	1
140	106	-	1
200	75	-	1
270	53	-	1
pan	37	-	-

Table 2. Influence of Balls and Brushes on Mean Particle Size and Standard Deviation of Ground Corn, Exp. 1[a]

Item	Balls and brushes	No balls and brushes	P<
Mean			
Grind 1	665 ± 9.6	755 ± 7.5	0.0001
Grind 2	458 ± 8.5	523 ± 12.4	0.002
Standard Deviation			
Grind 1	2.41 ± 0.012	2.00 ± 0.009	0.0001
Grind 2	2.13 ± 0.017	1.83 ± 0.019	0.0001

[a]Values are the means ± SE of 10 replications per treatment.

Table 3. Influence of Tapping Bar on Mean Particle Size and Standard Deviation of Ground Corn, Exp. 2[a]

Item	Tapping bar	No tapping bar	P<
Mean			
Grind 1	650 ± 2.9	640 ± 7.2	0.22
Grind 2	433 ± 4.7	440 ± 5.1	0.27
Standard Deviation			
Grind 1	2.44 ± .017	2.46 ± .008	0.18
Grind 2	2.24 ± .016	2.24 ± .019	0.95

[a]Values are the means ± SE of 10 replications per treatment.

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A COMPARISON OF DIFFERENT PARTICLE SIZE ANALYSIS TECHNIQUES

A. L. Baldridge, T. L. Stainbrook, J. C. Woodworth, M. D.Tokach, J. L. Nelssen, and R. D. Goodband

Summary

In this study, we compared different methods of testing particle size of ground corn. Forty-four corn samples were analyzed for particle size with a Ro-Tap tester equipped with a 13-sieve stack (53 to 3,350 ∶m tyler mesh screens). Mean particle size of the 44 samples ranged from 422 to 1,143 ∶m. These samples were then analyzed by placing 280 g on a #14 sieve (1,400 ∶m). The sieve was shaken by hand as the manufacturer recommended (one-sieve method). In a second procedure, samples were analyzed by placing 50 g of corn on a stack of three sieves: US #12 (1700 ∶m), #30 (600 ∶m), and #50 (300 ∶m: three-sieve method) with balls and carnucles. The three-sieve method was much more reliable in predicting average particle size of ground corn than the one-sieve method when compared to the 13-stack standard operating procedure. In summary, the three-sieve procedure may be a more accurate method to quickly determine particle size than the one-sieve method.

(Key Words: Ground Corn, Particle Size, Procedures.)

Introduction

The particle size of grain fed to swine and poultry has a major impact on feed efficiency. Because of the economic importance of particle size, nutritionist and consultants recommend frequent particle size analysis. The standard method for determining particle size is time consuming and requires a large initial investment. As a result, many swine producers use a fast, simple, one-sieve method for determining particle size. It is believed that the one screen method, although not as precise as the standard method, would be a suitable alternative to the standard procedure. However, recent variability in results between the one-sieve and standard method of particle size analysis led us to question the accuracy of the one sieve method. Therefore, the objective of our experiment was to compare results of a one- and three-sieve particle size analysis method to the standard Ro-Tap tester equipped with a 13-sieve stack. A second objective was to determine the required amount of time the three-sieve method needed to be shaken.

Procedures

Experiment 1. In our three-sieve method, 50 g of corn was placed on a stack of three sieves: US #12 (1700 ∶m), #30 (600 ∶m), and #50 (300 ∶m). There was one ball and one carnucle on the #30 sieve and one ball and two carnucles on the #50 sieve. A lightweight lid was placed on top of the stack to prevent spilling while a small pan was added on bottom to collect dust. The sieves were shaken vigorously by hand for five 30-second intervals. The sample left on each screen was then weighed between each interval.

This was repeated for 10 different corn samples. The change in the amount of grain left on each screen after every 30-second period was plotted to determine the most effective shaking time. We used this optimum shaking time in Exp. 2.

Experiment 2. We collected 44 samples of ground corn and determined particle size with a Ro-Tap tester equipped with a 13-sieve stack. The screens used included: US #6 (3,350 ∶m), #8 (2,360 ∶m), #12 (1,700

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：m), #16 (1,180 ：m), #20 (850 ：m), #30 (600 ：m), #40 (425 ：m), #50 (300 ：m), #70 (212 ：m), #100 (150 ：m), #140 (106 ：m), #200 (75 ：m), and #270 (53 ：m). The corn samples ranged from 422 to 1,143 ：m in particle size.

One-Sieve Method. According to directions provided with the one-sieve particle analysis kit (IFA, Stanly, IA), 280 g (10 oz) of grain was placed on a #14 sieve (1,400 ：m). The sieve was shaken by hand until it appeared that all the small particles had fallen through the screen. The sample was weighed and an average particle size was predicted by comparing the amount remaining on the screen to an equation we calculated from the information provided with the kit. According to kit instructions, particle size is calculated by the weight of the material remaining on the #14 screen rounded to the nearest ounce and correlating the weight to a particle size of 700, 800, 900, 1,000, and 1,200 microns. We developed the following equation to best fit the results to the values given by the instructions:

$$\text{Particle Size} = 12X+560$$

where X is the amount (g) of sample left on the screen. We then developed our own regression equation by correlating the known particle size of the sample to the amount of material left on the sieve for each sample. This second equation was (R^2=0.74):

$$\text{Particle Size} = 11.8637X + 435.2123.$$

Three-Sieve Method. Corn samples (50 g) were shaken for one minute and thirty seconds using the same three-sieve stack described in Exp. 1. The sample remaining on each sieve was weighed and then regressed to determine a predicted equation for particle size (R^2=0.88):

$$\text{Particle Size} = 18.892(X\#12) + 10.870(X\#30) + 1.1827(X\#50) – 149.978;$$

where X equals the percentage of sample on the respective screens. Predicted average particle sizes by the two procedures were compared to the particle size determined by the standard procedure using the Ro-Tap tester.

Results and Discussion

Experiment 1. Most of the grain was found to pass through the screens during the first minute and a half of shaking (Figure 1). This amount of time was both effective and practical (from the shakers standpoint). We then used this as the shaking time in Experiment 2.

Experiment 2. The results of the one- and three-sieve methods were compared to the results of the Ro-Tap tester in this experiment. The one-sieve method, using the regression equation provided by the manufacturer, was able to predict 14 of the 44 samples within 75 ：m of their actual size (Figure 2). Its prediction was off by more than 150 ：m on 20 samples, eight of which were predicted over 200 ：m from the actual particle size. Using the regression formula we developed for the one-sieve method, particle size was predicted slightly better with 11 samples off by more than 100 ：m (Figure 3).

The three-sieve method predicted 40 of the 44 samples to within 75 ：m and only 1 sample was off by more than 150 ：m (Figure 4). Fourteen of the samples were predicted within 25 ：m of the actual value. The advantage to the three-sieve method is that it requires no more time in shaking than the one-sieve and more accurately predicts particle size. However, there will be slightly more initial expense because three rather than one screens must be purchased. From our results, the three-sieve appears to be more accurate than the one sieve method.

While the three-sieve method predicts the average particle sizes more accurately than the one-sieve, it is still not as precise as the standard Ro-Tap tester and 13-sieve stack. If using either the one- or three-sieve methods, we recommend conducting multiple tests. In addition, samples should be sent periodically (i.e., once a month) to a laboratory that regularly performs particle size analysis to verify results of either the one- or three-sieve method.

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Figure 1. Average Amount of Grain Passing through the Three Screens During Each Time Interval.

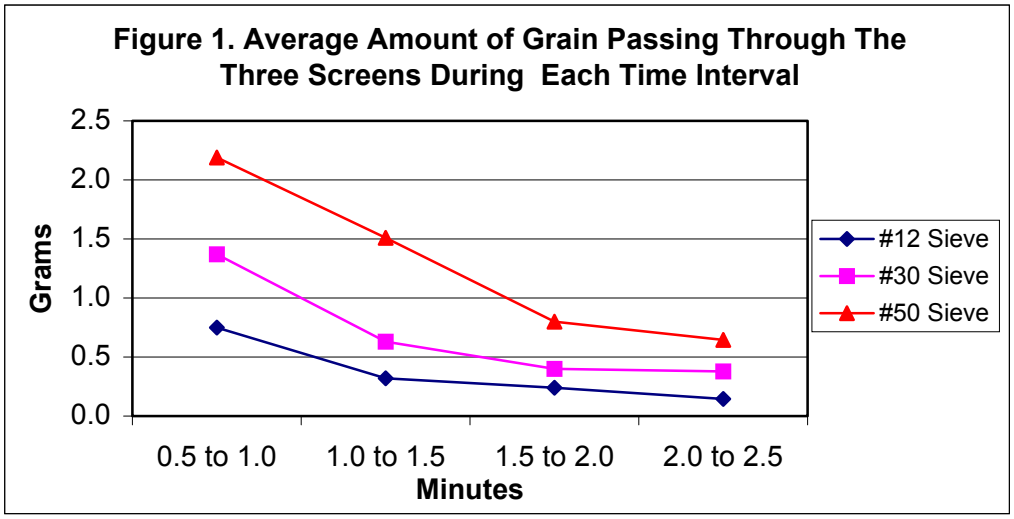

Figure 2. Distance from Actual Particle Size for Each Sample for the One Sieve Method following the Manufacturers Instructions (Particle Size = 12X + 560).

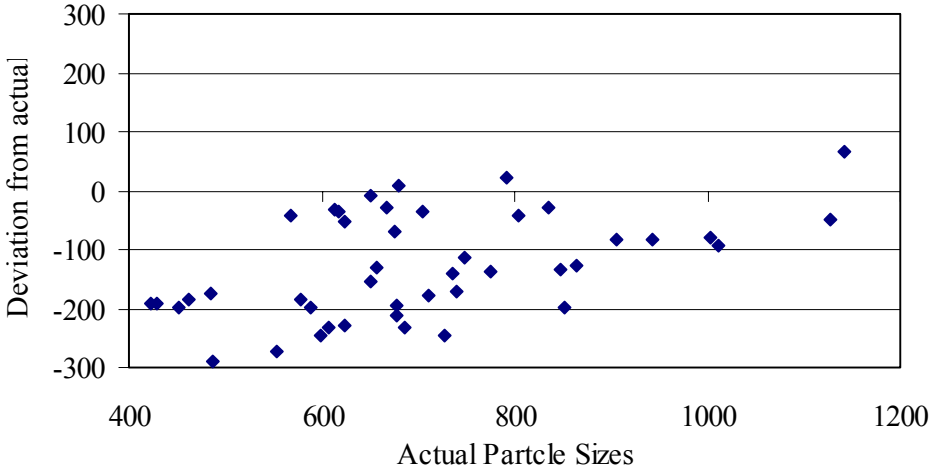

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Figure 3. Distance from Actual Particle Size for Each Sample for the One Sieve Method using a Regression Equation Developed from the samples (Particle Size = 11.8637X + 435).

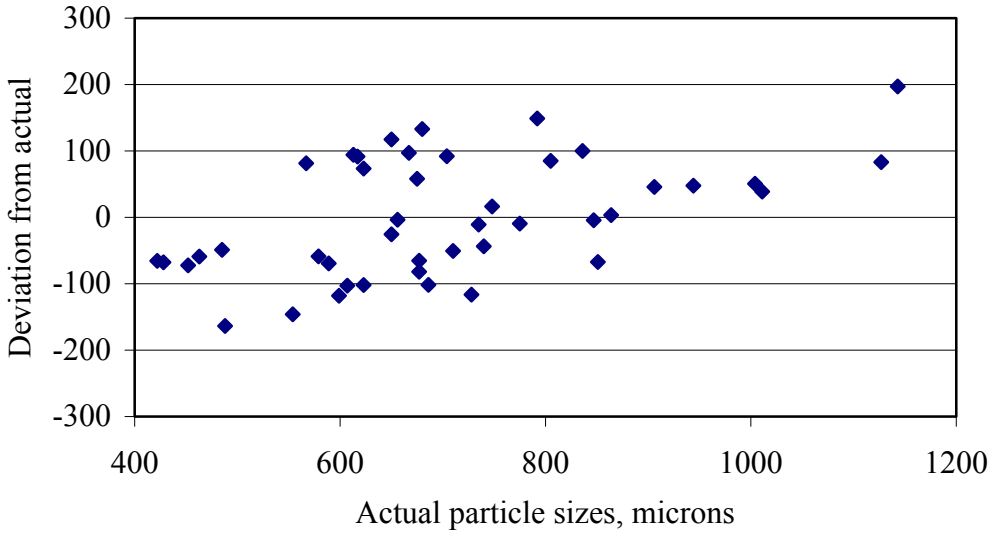
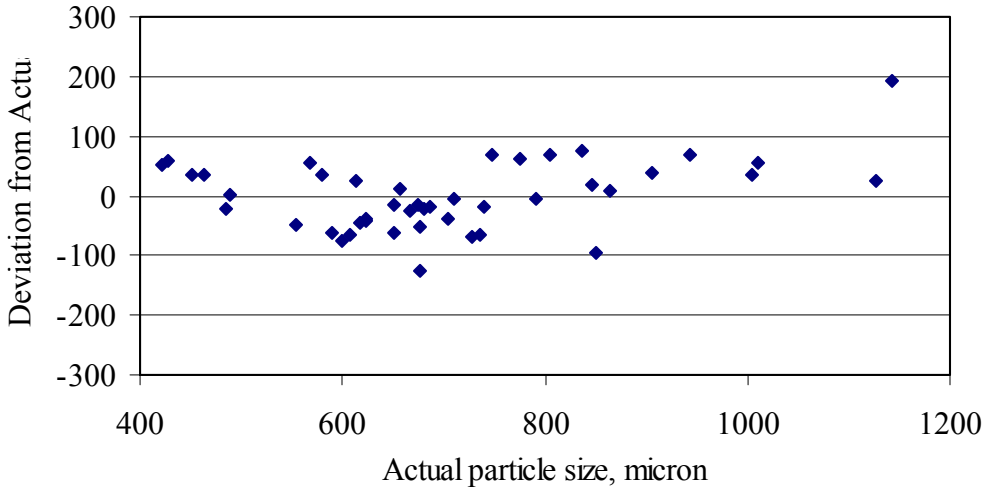


Figure 4. Distance from Actual Particle Size for Each Sample using the Three Sieve Procedure (Particle Size = 18.892(X#12) + 10.870(X#30) + 1.1827(X#50) – 149.978)



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Swine Industry Day Committee

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