INFLUENCE OF LIPOPOLYSACCHARIDE-INDUCED IMMUNE CHALLENGE AND DIET COMPLEXITY ON GROWTH PERFORMANCE AND ACUTE-PHASE PROTEIN PRODUCTION IN SEGREGATED EARLY-WEANED PIGS [1]

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Summary

When eating the same amount of feed, pair-fed pigs were more efficient at using nutrients for growth than pigs injected with lipopolysaccharide (LPS). Approximately 2/3 of the decreased growth of LPS-challenged pigs was due to decreased ADFI and 1/3 was due to decreased feed efficiency (F/G). Determining the optimum diet complexity for a nursery feeding program will depend on the desired balance between growth performance and feed cost per lb of gain but appears to be independent of immune response to inflammatory challenge. On a practical basis, this suggests that nursery diet complexity should not be influenced by health status.

(Key Words: Diet Complexity, Lipopolysaccharide, Growth.)

Introduction

The increased growth observed in segregated early weaning (SEW) production systems is thought to be a result of decreased stimulation of the immune system and is supported by research indicating that immune challenge results in decreased feed intake as well as partitioning nutrients away from growth. When developing production strategies that minimize immune challenge, it is important to determine if the reduced growth rate is a result of decreased feed intake and (or) nutrients being diverted away from growth to the immune response. These two causes have different economic costs. The goal when formulating nursery diets is to choose ingredients that are highly palatable and digestible. Because feed intake is decreased during an immune challenge, the selection and level of the highly palatable and digestible ingredients may be altered. If diet complexity can be reduced in pigs without an immune challenge while maintaining growth performance, diet cost and cost per unit of gain can be reduced. Therefore, our objective was to examine the influence of LPS-induced immune challenge and nursery diet complexity on the growth performance and plasma acute-phase protein production of SEW pigs.

Procedures

SEW pigs (initially 8.8 lb and 14 $\pm$ 1.5 d of age) were used to quantify the effects of LPS-induced immune challenge and nursery diet complexity (complex, medium, and simple) on growth performance and haptoglo-

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diet complexity (complex, medium, and simple) on growth performance and haptoglobin production. The three treatments of immune challenge consisted of pigs: 1) given ad libitum access to feed (control), 2) challenged with LPS and given ad libitum access to feed (LPS-challenged), and 3) pair-fed to receive the same amount of feed as the LPS-challenged pigs (pair-fed).

Pigs were housed in groups of five in pens (4 × 4 ft) with slotted metal flooring. The initial room temperature (90°F) was reduced by 2°F each week. Pigs had access to a nipple waterer and a self-feeder. Lipopolysaccharide was injected intramuscularly (68 μg/lb BW) on d 5, 8, 11, and 14 postweaning.

Pigs were fed a common diet from d 0 to 5 postweaning (Table 1). Pigs then were fed one of the three experimental diets from d 5 to 18 postweaning. All pigs then were fed a common corn soybean meal-based diet from d 18 to 32 postweaning.

Feeders in the pens containing the pigs injected with LPS were weighed daily to calculate feed disappearance for the previous 24 h. Subsequently, feed intake for the pair-fed pigs in each block was determined by taking the average feed intake for the previous 24 h of the two pens in each block challenged with LPS and adjusted up or down based on a comparison of the cumulative feed intake between pair-fed and LPS-challenged pens. The 24 h feed allotment for the pair-fed group was divided into four aliquots and fed every 6 h. Pig weights and feed consumption were determined on d 5, 8, 11, 14, 18, and 32 postweaning to calculate ADG, ADFI, and F/G. On d 8, 11, and 14 postweaning, plasma was collected from two pigs per pen. Plasma was analyzed for the immune response acute phase protein, haptoglobin. Data were analyzed as a randomized complete block design in a 3 × 3 factorial arrangement.

Results and Discussion

Means of responses are presented in Table 2. No interactions were observed for any of the response criteria between immune status and diet complexity ($P > .10$), indicating that the responses were independent. Therefore, if the LPS stimulation model is representative of the complex interplay of immunostimulants present in many commercial swine production systems, these results indicate that immune status does not need to be taken into account when determining the appropriate complexity of nursery diets.

From d 5 to 18 postweaning, ADG of the control pigs was higher ($P < .05$) than that of either the LPS-challenged or pair-fed pigs (Table 2). Average daily gain of the pair-fed pigs was higher than that of the pigs challenged with LPS ($P < .01$), although both groups of pigs ate the same amounts of feed ($P > .10$). The control pigs had higher ($P < .05$) ADFI than either the LPS-challenged or pair-fed pigs. The pair-fed pigs had improved F/G ($P < .05$) compared to the LPS-challenged pigs for that time period. The pair-fed pigs also had improved F/G compared to the control pigs ($P < .05$). No difference occurred in F/G between LPS-challenged and control pigs ($P > .10$).

The increased ADG of the pair-fed pigs compared to the pigs challenged with LPS was due to the pair-fed pigs having a better F/G. This can be explained by the fact that LPS has been shown to increase metabolic heat production. Because more energy is partitioned to metabolic heat production, the efficiency of utilization of dietary energy and, therefore, the efficiency of growth is reduced.

The increased F/G of the pair-fed pigs compared to control pigs can be accounted for by the fact that heat production is lower in animals fed below ad libitum. Heat production is related to energy intake and BW. Approximately 26% of energy intake is partitioned to heat production. Thus, the metabolic heat production in immune-challenged pigs was the sum of the increased rate from immune stimulation and the decreased rate from decreased feed intake.

When all pigs were fed a common diet from d 18 to 32 postweaning, ADG of the

LPS-challenged pigs was similar to that of the pair-fed pigs. However, pigs previously challenged with LPS had lower ADFI than either the control ($P<.10$) or pair-fed ($P<.01$) pigs. The lower ADFI of the LPS-challenged pigs indicates a carryover effect of LPS-induced immune challenge on feed intake.

The control pigs were heavier ($P<.01$) than either the LPS-challenged or pair-fed pigs on d 18 and 32 postweaning. Pair-fed pigs were heavier ($P<.01$) than the LPS-challenged pigs on d 18 and 32 postweaning. The difference in weight on d 18 postweaning between the pair-fed and control pigs was due to the decreased growth from decreased feed intake by the former. The difference in weights between the LPS and pair-fed pigs probably was due to the different efficiency of nutrient use for growth, because both groups ate the same amount of feed. Consequently, the 2.4-lb decrease in weight per pig at d 18 postweaning of the LPS-challenged pigs compared to the control pigs was the result of both decreased efficiency of gain and decreased feed intake. The .9 lb difference in pig weight between pair-fed and pigs injected with LPS was due to the decreased efficiency of gain from immune challenge, and the 1.5 lb difference in pig weight between control and pair-fed pigs was indicative of the amount of decreased growth from the lower feed intake of the LPS and pair-fed pigs.

The magnitude of the ratio between the two factors is important for economic considerations, because inefficient nutrient use for growth will have a larger economic impact than decreased nutrient intake. This is because the former incurs the expense of the increased nutrients used per unit of output (gain). Although decreased nutrient intake results in decreased gain, it does not incur increased cost per unit of gain. The only cost incurred is the lost opportunity cost that more pounds of pork can be generated per unit of time and space

From d 5 to 18 postweaning, pigs fed the complex diets had greater ADG and ADFI ($P<.05$) than pigs fed either the medium or simple diets (Table 2). Furthermore, pigs fed the medium complexity diet had greater ADG and ADFI ($P<.05$) than pigs fed the simple diet from d 5 to 18 postweaning. Pigs fed the complex and medium diets had better F/G ($P<.05$) than pigs fed the simple diets. The growth performance indicates that the difference between pigs fed the complex and medium diets was solely due to the pigs fed the complex diet eating more feed per day. The differences between pigs fed the simple diet and medium or complex diets was due to decreased ADFI and increased F/G. The increased F/G of pigs fed the simple diet could be an indication that either the ingredients used were not as digestible or the absorptive capacity of the intestine was damaged by the diet.

For the overall d 5 to 32 postweaning period, pigs fed the complex and medium diets had higher ADG ($P<.05$) than pigs fed the simple diets. No differences ($P>.10$) were observed in ADFI. Feed efficiency was similar ($P>.10$) between pigs fed the complex or medium diets; however, pigs fed the complex or medium diets had improved F/G ($P<.05$) than pigs fed the simple diet for the overall period. The increased F/G of pigs previously fed the simple diet compared to pigs previously fed the complex or medium diets in the subsequent d 18 to 32 postweaning period when all pigs were fed the same diet indicates that the absorptive capacity of the intestine was compromised by the diet fed from d 5 to 18 postweaning. Pigs fed the simple diets had a 6.7% poorer F/G for the overall d 5 to 32 postweaning period compared to pigs fed the complex or medium diets.

No diet by immune status interactions occurred ($P>.10$) for haptoglobin concentration. Pigs injected with LPS had higher ($P<.01$) mean haptoglobin concentrations than control or pair-fed pigs. Diet did not have an effect ($P>.10$) on haptoglobin concentration. Lipopolysaccharide is a potent stimulator of inflammatory cytokine production leading to acute-phase protein production. Thus, increased haptoglobin concentrations in the pigs injected with LPS indicate increased inflammatory cytokine production.

However, the lack of an influence of diet on haptoglobin concentration suggests that diet complexity does not influence feed intake by altering the balance of inflammatory cytokines.

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

	d 0 to 5	d 5 to 18 postweaning			d 18 to 32
Ingredient, %	postweaning	Complex	Medium	Simple	postweaning
Corn	31.80	37.70	35.59	36.35	60.94
Soybean meal (46.5% CP)	--	--	28.12	49.00	34.74
Moist extruded soy protein concentrate	8.58	9.96	--	--	--
Dried whey, edible-grade	30.00	20.00	20.00	5.00	--
Lactose	5.00	8.50	--	--	--
Select menhaden fish meal	6.00	6.00	2.50	--	--
Spray-dried plasma protein	7.50	7.50	2.50	--	--
Spray-dried blood meal	1.75	1.75	2.50	--	--
Soy oil	6.00	5.00	5.00	5.00	--
Monocalcium phosphate (21% P)	1.13	1.37	1.35	1.63	1.45
Limestone	.21	.30	.51	.79	.90
Antibiotic[b]	1.00	1.00	1.00	1.00	1.00
Zinc oxide	.38	.38	.38	.38	--
Copper sulfate	--	--	--	--	.075
Salt	--	.05	.05	.37	.35
Vitamin premix	.25	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15	.15
DL-Methionine	.15	.08	.10	.08	.025
L-Lysine·HCl	.10	--	--	--	.13
Total	100.00	100.00	100.00	100.00	100.00
Calculated composition, %					
Lysine	1.70	1.60	1.60	1.60	1.30
Methionine	.50	.44	.47	.44	.36
Methionine + cystine	.95	.88	.88	.90	.75

[a]Diets were formulated to contain .9% Ca and .8% P.
[b]To provide 25 μg/lb carbadox.

Table 2. Influence of LPS-Induced Immune Challenge and Diet Complexity on Growth Performance and Haptoglobin Production[a]

	Control			LPS-challenged			Pair-fed			P value (P<)		
Item	Complex	Medium	Simple	Complex	Medium	Simple	Complex	Medium	Simple	Immune	Diet	CV
Day 5 to 18 postweaning												
ADG, lb	.81[b,e]	.73[b,f]	.62[b,g]	.60[c,e]	.55[c,f]	.48[c,g]	.63[d,e]	.63[c,f]	.53[d,g]	.01	.01	9.4
ADFI, lb	.88[b,e]	.82[b,f]	.74[b,g]	.66[c,e]	.62[c,f]	.57[c,g]	.65[c,e]	.62[c,f]	.57[c,g]	.01	.01	6.8
F/G	1.09 [b,e]	1.14 [b,e]	1.19[b,f]	1.11[b,e]	1.12[b,e]	1.19[b,f]	1.03[c,e]	.98[c,e]	1.06[c,f]	.01	.01	6.7
Day 18 to 32 postweaning												
ADG, lb	1.25	1.24	1.28	1.19	1.20	1.24	1.23	1.22	1.22	.14	.52	5.8
ADFI, lb	1.86[b,c]	1.81[b,c]	1.94[b,c]	1.71[b]	1.79[b]	1.87[b]	1.93[c]	1.78[c]	1.94[c]	.07	.03	6.9
F/G	1.49	1.45	1.52	1.43	1.49	1.52	1.54	1.45	1.59	.27	.14	6.6
Day 5 to 32 postweaning												
ADG, lb	1.04[b,e]	1.00[b,e,f]	.96[b,f]	.91[c,e]	.88[c,e,f]	.87[c,e]	.95[b,e]	.94[b,e,f]	.89[b,e]	.01	.01	4.9
ADFI, lb	1.39[b]	1.34[b]	1.36[b]	1.21[c]	1.22[c]	1.25[c]	1.32[c]	1.22[c]	1.28[c]	.01	.17	5.7
F/G	1.33[e]	1.33[e]	1.41[f]	1.33[e]	1.39[e]	1.43[f]	1.39[e]	1.30[e]	1.43[f]	.80	.01	5.6
Pig weight, lb												
d 18 postweaning	21.4[b,e]	20.5[b,f]	19.0[b,g]	18.7[c,e]	18.1[c,f]	17.2[c,g]	19.2[d,e]	19.2[d,f]	17.9[d,g]	.01	.01	4.0
d 32 postweaning	39.0[b,e]	37.7[b,e,f]	36.8[b,f]	35.3[c,e]	34.8[c,e,f]	34.4[c,f]	36.4[d,e]	36.1[d,e,f]	35.0[d,e]	.01	.01	3.5
Haptoglobin, mgHgb/dL	10.7[b]	8.7[b]	10.5[b]	28.0[c]	19.4[c]	22.4[c]	7.8[b]	6.4[b]	11.7[b]	.01	.17	112

[a]All pigs were fed a complex common diet from d 0 to 5 postweaning. Pigs then were fed the complex, medium, and simple diets from d 5 to 18 postweaning. All pigs were fed a common diet from d 18 to 32 postweaning. The pigs challenged with LPS were injected with LPS (68 μg/lb BW) on d 5, 8, 11, and 14 postweaning. Weight on d 5 postweaning was used as a covariate. Each number represents the mean of 6 pens with 5 pigs per pen. Pigs were 8.8 lb and 14 ± 1.5 d of age at weaning. Interactions between immune status and diet complexity were not observed (P>.10) for any of the response criteria.

[b,c,d] Means within the main effect of immune challenge and within row lacking a common superscript letter differ (P<.05).

[e,f,g] Means within the main effect of diet complexity and within row lacking a common superscript letter differ (P<.05).