Effects of Addition of Fructooligosaccharide (FOS) and Sugar Beet Pulp to Weanling Pig Diets on Performance, Microflora and Intestinal Health

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Introduction

The period around weaning is a critical time in the life of a young piglet. The change from milk to solid feed, the absence of maternal immunoglobulins, and the stress of a change of environment and littermates can endanger the intestinal health of the animal. The immune system of the pig is not fully developed, and this makes the animal vulnerable to the activity of pathogens.

To reduce stress during this transition and decrease the negative effects on the pig's health, subtherapeutic levels of feed grade antibiotics are used extensively. However, the use of antibiotics in animal feed is a cause for concern, because of the risk of selection of resistant strains of microorganisms. A total ban on several feed grade antibiotics may result in the near future. To maintain animal health and productivity in such a scenario, alternatives have to be evaluated.

One of the alternatives for growth promoting antibiotics could be the concept of prebiotics. The concept is based on the phenomenon of colonial resistance, in which beneficial bacteria like Bidifobacteria and Lactobacilli control opportunist pathogens like *E. coli* and Salmonella, mainly through secretion of volatile fatty acids (VFA) and competition for nutrients and binding sites (Koopman et al., 1999). Prebiotics have to selectively stimulate the activity and/or growth of these beneficial bacteria in the intestinal tract (Gibson et al., 1995). A lot of research in this area has focused on fructooligosaccharides (FOS). In one of these studies, Houdijk (1998) concluded that the FOS was fermented before it reached its intended destination, the colon, and therefore could not serve as a substrate for Bifidobacteria there.

A slowly fermentable source of carbohydrates might accommodate a continuous flow of substrate for the beneficial bacteria throughout the ileum and the colon. The VFA production as a result of that fermentation capacity could help protect the animal against the pathogenic activity. In this study, FOS was used as a rapidly fermentable source of carbohydrates and sugar beet pulp as a slowly fermentable source. The objective of this study was to investigate the effects of adding FOS and sugar beet pulp to weanling pig diets on performance, intestinal VFA patterns, intestinal microbial counts and the general health status of the pig. In addition, the study was to determine whether these ingredients stimulate fermentation in the intestinal tract and therefore help protect the animal from colonization of threatening strains of bacteria. If so, this could be an alternative to the use of feed grade antibiotics.

Materials and Methods

A group feeding study was conducted consisting of two trials with 175 pigs each in two different nurseries. One of the nurseries was cleaned and disinfected before the experimental group was brought in, and the other one was not. The two trials were started within a 2-week interval. A total of 25 pens were used within each nursery, with 5 dietary treatments assigned at random to 5 replicate pens blocked within the room. Each pen contained 7 pigs, 3 barrows and 4 gilts, at similar initial weights. The pigs were weaned at 26 to 28 days of age. The following 5 diets were formulated (Table 1):

- Negative control diet (NEG), without any of the experimental ingredients.
- Antibiotic diet (AB), containing Virginiamycin (Stafac) as a feed grade antibiotic at 0.05% of the diet.
- Fructooligosaccharide diet (FOS), containing FOS at 5% of the diet.
- Beet pulp diet (BP), containing sugar beet pulp at 10% of the diet.
- Combination diet (COM), containing a mixture of FOS at 2.5% and sugar beet pulp at 5% of the diet.

The animals were fed their respective diets for a period of 4 weeks. The live weight of individual pigs and pen feed intake data were recorded weekly. Incidence of diarrhea was scored daily. At the end of the trial, blood samples were taken randomly from two pigs in each pen for insulin-like growth factor-1 (IGF-1) analysis. At the end of the trial, one animal from each pen was selected and sacrificed. Lungs, liver, spleen, ileal-cecal lymph nodes and the gastrointestinal tract (GIT) were evaluated. GIT samples were taken from the terminal ileum, proximal colon and distal colon. These sample sites were selected because they present an image of bacterial and fermentation characteristics throughout the GIT. The samples were analyzed for *E. coli,* Bifidobacteria and total anaerobic bacterial counts, as well as VFA composition. Statistically, each trial was analyzed separately.

Results

Average daily gains were not significantly changed by dietary treatment in both the clean and dirty nursery trials (Table 2). There was a trend towards an increased gain of pigs in week 4 comparing the COM diet with pigs fed the BP diet in the clean nursery trial. Overall, the AB diet, FOS diet and COM diet increased gains 16%, 9% and 6%, respectively, compared to the NEG control in the clean nursery trial. In the dirty nursery trial, feed efficiency was improved 14% with the FOS diet compared to the NEG diet. However, feed intakes were reduced with the FOS diet by 24% compared to the NEG diet in the dirty nursery trial.

There were little differences in diarrhea scores or the apparent health status of the organs in the pigs based upon gross necropsy at the end of each trial. There was a non-statistical trend of less diarrhea with all treatments (especially the BP diet) compared to the NEG diet in the clean nursery. Diarrhea incidences were higher in the dirty nursery trial, compared to the clean nursery, but there were no obvious treatment differences. Mortality during the study was necropsied at the Purdue Animal Disease Diagnostic Laboratory with *Streptococcus suis* as the causative agent, but these cases were not related to any dietary treatments. Week 4 serum IGF-1 results showed a trend towards lower IGF-1 values from pigs fed the BP diet compared to the

other treatments only in the clean nursery trial; however, there were no significant treatment differences (Table 2).

Although not significant, there was a trend towards lower *E. coli* concentrations in terminal ileal contents with pigs fed the FOS and BP diets in the clean nursery trial. FOS increased Bifidobacteria in proximal colon samples of pigs in both the clean and dirty nurseries (Table 3). *E. coli* was reduced in the proximal colon of pigs fed FOS and BP diets in the clean nursery. The greatest fermentation activity in the proximal colon was in pigs fed the BP and COM diets, with acetic acid levels higher then other dietary treatments, especially in pigs fed the COM diet.

FOS reduced the *E. coli* concentrations and increased Bifidobacteria concentrations in the distal colon of the pigs, especially in the clean nursery trial (Table 3). BP-fed pigs had lower *E. coli* levels in the distal colon. Total anaerobic bacteria concentrations were elevated in the distal colon with the FOS diet. There were little differences in VFA composition in the distal colon, but there was a trend towards higher total fermentation values with pigs fed the BP and COM diets.

Discussion

The focus of this nursery study was to determine the effect of using two types of oligosaccharides in non-antibiotic diets on nursery pig growth and general health status. As an added stress in one trial, the nursery was not cleaned between groups of pigs. The pelleted diets used alternative sources of protein (fish meal and soy isolates) in the basal mix and were balanced to have similar metabolizable energy values, protein levels and minerals. Typically, milk product-based diets are used in the nursery, and the resultant lower gains and feed intake of pigs in this trial compared to the average on the farm were probably due to the experimental diets not being milk-based. However, these diets were used so that the specific oligosaccharides could be tested effectively in the experiment and would not be masked by the high oligosaccharides in the milk-based diets.

During the clean nursery trial, drafts created by ventilation problems potentially added stress to a number of pigs in the room. Consequently, there were indications that the FOS or the combination of FOS and sugar beet pulp (COM) increased gains of the pigs but still less than the antibiotic diet. In the dirty nursery trial, the only indication of FOS benefit was with improved feed efficiency in the nursery room with no ventilation problems. No performance response to the antibiotic is surprising, with no clear explanation for this result. It was noted that feed intake was reduced for the 5% FOS diet during both trials, which has been observed in previous research (Houdijk, 1998). For the diet combining FOS with sugar beet pulp, intake was increased to similar levels as the other experimental diets.

There was no response to 10% sugar beet pulp in the pig's diet. Due to the transition from a milk diet to dry feed and potentially insufficient bacteria established in the lower digestive system to ferment this fibrous material, sugar beet pulp alone is not sufficient to sustain rapid growth at this age. However, later in the trial, the increased intake and growth was evident. This was supported by the fact that more VFAs were produced in the proximal and distal colon in pigs fed the BP or COM diets.

Since FOS is highly digestible and appears to be fermented rather rapidly in the small intestine of the pig, the concept of adding a carbohydrate that would bypass the small intestine but would support fermentation in the lower intestine has merit. In this trial, addition of sugar beet pulp did increase fermentation (increased VFAs) and reduce *E. coli* levels, but did not support increased gains. It has been established that certain oligosaccharides will sustain higher levels of Bifidobacteria, which was also observed with FOS in this study. Research is needed to ascertain the reason why feed intakes are lower with FOS placed in the diet. This may be accomplished through either reducing the dietary level of FOS or adding something to stimulate diet intake.

The combination of both the rapidly fermentable and slowly fermentable oligosaccharides in the pig's diet did not yield improved performance results. However, if this theory can be used to successfully maintain pig growth and health, then the correct ratio of each ingredient and fermentability of the oligosaccharide sources must be studied and refined for optimal productivity.

Implications

Specific oligosaccharides in weanling pig diets may help temper the transition from milk diets to dry feed, though performance may not reach the levels found when antibiotics are included in the diet. Within the normal stresses of a production type environment, use of FOS or sugar beet pulp helped in maintaining a healthy GIT environment through greater colonization of Bifidobacteria or reduction of *E. coli* in the intestinal system. Further research is needed to determine if changing levels of various oligosaccharides can also provide consistent efficient pig gains and feed conversion.

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Table 1. Composition of experimental diets (% of diet).

Ingredient	NEG	AB	FOS	BP	COM
Yellow corn	27.85	27.85	24.91	22.86	23.97
Corn starch[a]	22.25	22.2	20.06	18.38	19.19
FOS[b]	0	0	5	0	2.5
Beet pulp	0	0	0	10	5
Fish meal	23	23	23	23	23
Dextrose	15	15	15	15	15
Cellulose	1	1	1	1	1
Premix[c]	1	1	1	1	1
Soy isolate[d]	4	4	4.1	3	3.5
Fat	4	4	4	4	4
Ca CO_3	0.35	0.35	0.37	0.17	0.26
Ca PO_4	0.34	0.34	0.33	0.33	0.33
Na Cl	0.1	0.1	0.1	0.1	0.1
L-lysine-HCl	0	0	0	0	0
DL-Methionine	0.02	0.02	0.03	0.05	0.04
L-Threonine	0.06	0.06	0.06	0.07	0.07
L-Trptophan	0.03	0.03	0.04	0.04	0.04
Diamol[e]	1	1	1	1	1
Stafac[f]	0	0.05	0	0	0
Nutrients[g]					
CP (%)	19.5	20.1	20.0	20.0	20.0
ME (Kcal)	3523	3521	3471	3415	3443
CF (%)	1.6	1.6	1.6	3.2	2.4
Total ash (%)	4.8	4.8	4.8	5.2	5.0
Total Ca (%)	1.04	1.04	1.04	1.03	1.04
Total P (%)	0.83	0.83	0.82	0.81	0.82
Lysine (%)	1.38	1.38	1.38	1.37	1.37

[a] Corn starch provided by A.E. Staley Co., West Lafayette, IN.
[b] Fructooligosaccharide (Raftilose® P95) provided by ORAFTI Food Ingredients, Malvern, PA.
[c] Vitamin-mineral premix.
[d] Soy isolate (85% crude protein) provided by ADM, Decatur, IL.
[e] Diamol is acid insoluble ash used as a marker.
[f] Virginiamycin.
[g] Calculated values except nitrogen which are analyzed values.

Table 2. Performance and serum IGF-1 of pigs fed experimental diets in a clean nursery room and a dirty nursery room.

	Clean Nursery					Dirty Nursery				
	NEG	AB	FOS	BP	COM	NEG	AB	FOS	BP	COM
ADG (lb/d)										
Week 1	0.39	0.35	0.31	0.30	0.30	0.22	0.16	0.20	0.27	0.25
Week 2	0.38	0.55	0.46	0.45	0.40	0.43	0.31	0.30	0.41	0.34
Week 3	0.53	0.65	0.63	0.66	0.52	0.67	0.58	0.57	0.74	0.72
Week 4	0.84	0.93	0.93	0.72	1.04	1.03	0.98	0.96	0.99	1.04
Overall	0.53	0.62	0.58	0.53	0.56	0.58	0.51	0.51	0.60	0.60
Daily Feed Intake (lb/d)										
Week 1	0.42[a]	0.42[a]	0.42[a]	0.33[b]	0.36[ab]	0.28	0.25	0.24	0.33	0.30
Week 2	0.68	0.77	0.78	0.76	0.71	0.62	0.53	0.54	0.66	0.64
Week 3	0.95	1.01	1.03	1.00	1.07	1.02[ab]	0.97[ab]	0.88[b]	1.16[a]	1.06[ab]
Week 4	1.96[ab]	2.15[ab]	1.87[b]	1.98[ab]	2.25[a]	1.47	1.29	1.12	1.48	1.52
Overall	1.00	1.07	1.02	1.00	1.06	0.83[ab]	0.74[ab]	0.63[b]	0.89[a]	0.87[a]
Feed:Gain										
Week 1	1.11	1.20	1.40	1.37	1.63	1.34	2.01	1.27	1.26	1.29
Week 2	1.88	1.41	1.77	1.88	1.81	1.51	1.73	1.92	1.64	1.84
Week 3	1.83	1.54	1.68	1.65	2.12	1.53	1.68	1.60	1.57	1.47
Week 4	2.47	2.40	2.20	2.98	2.20	1.43	1.31	1.06	1.51	1.45
Overall	1.89	1.72	1.77	1.90	1.89	1.43[ab]	1.44[ab]	1.23[b]	1.48[a]	1.46[a]
Serum IGF-1 (ng/ml)	98.1	107.8	101.8	70.9	103.3	99.1	86.4	99.1	91.3	112.9

[a,b] Means in a row with different superscripts differ, P<.05.

Table 3. Microbial results of the proximal and distal colon samples.

	Clean Nursery					Dirty Nursery				
Trait	NEG	AB	FOS	BP	COM	NEG	AB	FOS	BP	COM
Proximal colon										
Log counts:										
E. coli	6.30[ab]	6.71[a]	5.05[b]	5.01[b]	5.94[ab]	5.99	6.74	5.72	5.37	6.26
Bifidobacteria	8.10	8.27	8.64	8.09	8.27	8.70[ab]	8.81[ab]	9.28[a]	8.44[b]	8.52[ab]
Total anaerobes	9.72	9.79	10.12	9.57	9.99	10.30[ab]	10.08[ab]	10.51[a]	10.00[b]	10.05[b]
VFA, mmol/L:										
Acetic acid	89.6[ab]	84.9[b]	90.6[b]	97.3[ab]	116.5[a]	84.6	83.7	77.7	100.2	99.8
Propionic acid	33.6	42.2	39.0	35.0	44.5	32.5	30.6	40.9	37.1	42.1
Butyric acid	12.8	18.9	20.2	12.4	16.2	15.7	13.9	13.0	15.8	21.4
Isobutyric acid	1.4	1.9	1.3	0.8	0.9	2.2[a]	2.1[a]	1.0[b]	1.3[ab]	1.4[ab]
Isovaleric acid	0	0.6	1.6	0	0	1.3	1.1	0	0.4	0.9
Valeric acid	3.2	2.5	4.9	2.3	2.3	4.0	3.8	3.0	3.5	3.3
Total VFA	140.6	150.9	157.5	147.9	180.4	140.3	135.3	135.6	158.2	168.9
Distal colon										
Log counts:										
E. coli	6.09[a]	6.73[a]	4.78[ab]	3.95[b]	5.65[ab]	5.55	6.61	5.31	4.96	6.34
Bifidobacteria	8.01[b]	8.26[ab]	9.25[a]	8.43[ab]	8.27[ab]	8.45	8.42	9.07	8.42	8.63
Total anaerobes	9.71[b]	9.73[b]	10.26[a]	9.71[b]	9.64[b]	10.08	9.90	10.20	9.98	9.95
VFA, mmol/L:										
Acetic acid	47.5	46.7	50.0	69.6	71.0	69.9	55.3	55.3	76.4	80.0
Propionic acid	16.1	25.0	16.7	21.4	22.1	26.0	17.2	20.9	25.5	27.0
Butyric acid	4.9	4.8	5.5	12.8	11.5	10.8	7.3	4.7	9.8	12.8
Isobutyric acid	1.1	6.1	2.1	1.9	1.9	2.2	2.2	1.4	1.6	2.3
Isovaleric acid	0	0	0	0.8	0	0.7	1.1	0.8	0.9	0.9
Valeric acid	1.3	1.0	0	2.6	2.1	2.8	2.0	1.9	2.8	2.9
Total VFA	70.9	83.6	74.2	109.1	108.6	112.5	84.9	85.0	117.0	125.9

[a,b] Means in a row with different superscripts differ, P<.05.