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Effects of full fat or defatted rice bran on growth performance and blood characteristics of weanling pigs[1]

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ABSTRACT: The objective of this experiment was to determine the effect of increased concentrations of full fat rice bran (FFRB) or defatted rice bran (DFRB) in diets without or with supplementation of an exogenous xylanase on growth performance and blood characteristics in weanling pigs. A total of 532 pigs (9.3 ± 0.5 kg initial BW) were allotted to 14 diets in 4 blocks and 8 replicate pens per diet in a randomized complete block design. There were 4 or 5 pigs per pen. A basal diet containing corn, soybean meal, and whey powder and 6 diets containing corn, soybean meal, whey powder, and 10, 20, or 30% FFRB or 10, 20, or 30% DFRB were used. Seven additional diets that were similar to the initial 7 diets with the exception that they also contained 16,000 units/kg of microbial xylanase were also formulated. On the last day of the 23-d experiment, 2 blood samples were collected from 1 pig in each pen. Tumor necrosis factor-α (TNF-α), IgA, and peptide YY (PYY) were measured in plasma samples and blood urea nitrogen (BUN), total protein, and albumin were measured in serum samples. Initial and final BW were not affected by the inclusion level of FFRB or DFRB or by the addition of xylanase. The ADFI linearly decreased ($P < 0.05$) as inclusion of FFRB increased in diets and there was a tendency ($P = 0.08$) for reduced ADFI as DFRB was increased in the diets. Pigs fed diets containing DFRB had greater ADFI ($P < 0.05$) than pigs fed diets containing FFRB. The ADG increased and then decreased (quadratic, $P < 0.05$) with increasing level of FFRB or DFRB in the diets. The G:F linearly and quadratically increased ($P < 0.05$) as the inclusion of FFRB increased, and the G:F was greater ($P < 0.05$) in pigs fed diets containing FFRB than in pigs fed diets containing DFRB. The concentration of BUN linearly decreased ($P < 0.05$) when pigs were fed diets containing increasing levels of FFRB or DFRB. There was a tendency for the concentrations of TNF-α and PYY to linearly decrease ($P = 0.09$ and $P = 0.075$, respectively) as the inclusion of FFRB increased in the diet. In conclusion, ADG of weanling pigs was not affected by at least 20% FFRB or DFRB and inclusion of 30% DFRB had no effect on the G:F whereas 30% FFRB increased the G:F. However, microbial xylanase did not influence growth performance under the conditions of this experiment and there was minimal influence of rice coproducts or xylanase on blood characteristics.

Key words: growth performance, rice bran, rice coproducts, weanling pigs, xylanase

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INTRODUCTION

Rice bran is a coproduct of rice milling and represents approximately 12.4% of paddy rice (Sernaldívar, 2010). Concentrations of total dietary fiber and soluble dietary fiber in full fat rice bran (**FFRB**) and defatted rice bran (**DFRB**) range between 20 and 50% and between 2 and 3%, respectively (Hargrove, 1994; NRC, 2012). Soluble dietary fiber may be fermented by intestinal microbes and may promote colonization of a healthy intestinal microbiota (Herfel et al., 2013). Inclusion of 10% FFRB in diets fed to mice increased serum concentrations of IgA, indicating an improved immune response, and also increased colonization of *Lactobacillus*, which

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indicates that consumption of rice bran may induce a prebiotic effect in mice (Henderson et al., 2012). Ingredients with prebiotic effects usually reduce infection by pathogens, resulting in a reduced inflammatory response (Henderson et al., 2012). Likewise, inclusion of 10% stabilized FFRB improved feed efficiency and increased the concentration of colonic bifidobacteria in weanling pigs (21 to 49 d), indicating that stabilized FFRB also may have prebiotic properties in weanling pigs (Herfel et al., 2013).

However, the high concentration of nonstarch polysaccharides (**NSP**) in rice coproducts may have negative effects on the utilization of nutrients by pigs and may restrict the inclusion in diets. Addition of exogenous xylanase to wheat coproducts, which also have high concentrations of NSP, may improve digestibility of energy (Nortey et al., 2007; Zijlstra et al., 2010), and recent data from our laboratory indicate that the DE and ME in both FFRB and DFRB are increased if exogenous xylanase is added to the diet (Casas and Stein, 2016). Therefore, the objectives of this experiment were to determine the effects of increased inclusions of FFRB or DFRB in diets without or with exogenous xylanase on growth performance and blood concentrations of indicators for protein utilization, inflammatory responses, and prebiotic effects.

MATERIALS AND METHODS

The protocol for this experiment was reviewed and approved by the Institutional Animal Care and Use Committee at the University of Illinois.

Animals and Housing

A total of 532 pigs were weaned at 3 wk of age, fed a common diet for 2 wk after weaning, and then allotted to treatments using a completely randomized block design (9.3 ± 0.5 kg initial BW). Pigs were blocked by farrowing group with 2 replicates selected from each of 4 farrowing groups, with groups farrowing every other week. Pigs were the offspring of Line 359 boars mated to C-46 sows (Pig Improvement Company, Hendersonville, TN). Pigs were allotted to 14 dietary treatments, with 28 pens of 5 pigs (3 gilts and 2 barrows or 2 gilts and 3 barrows) in blocks 1, 2, and 4 and 28 pens of 4 pigs (2 gilts and 2 barrows) in block 3. There were 2 replicate treatments per block for a total of 8 replicates per treatment. Pigs were housed in pens (1.2 by 1.4 m) with fully slatted plastic floors for block 1 and 2 and mesh floors for blocks 3 and 4; each pen was equipped with a feeder and a nipple drinker, and the room temperature was set at 28°C at the beginning of the experiment and reduced by 1°C/wk thereafter.

Table 1. Analyzed nutrient composition of corn, soybean meal, whey powder, full fat rice bran (FFRB), and defatted rice bran (DFRB)

	Ingredients				
Item	Corn	Soybean meal	Whey powder	FFRB	DFRB
GE, kcal/kg	3,929	4,170	3,720	4,856	3,952
DM, %	88.47	88.37	86.84	96.45	90.16
CP, %	6.69	47.27	13.2	13.42	16.28
AEE,[1] %	3.35	1.63	1.95	19.51	7.11
Ash, %	8.02	8.68	7.75	9.4	13.14
Starch,	56.97	0.92	0.35	21.89	18.58
ADF, %	2.36	5.17	–	8.43	9.17
NDF, %	7.15	6.82	–	15.24	18.1
Ca, %	0.04	0.56	0.51	0.04	0.90
P, %	0.22	0.57	0.63	1.78	1.95
Indispensable AA, %					
Arg	0.29	3.42	0.38	1.05	1.28
His	0.23	1.36	0.29	0.40	0.47
Ile	0.24	2.21	0.62	0.48	0.57
Leu	0.81	3.61	1.15	0.93	1.10
Lys	0.24	2.97	0.98	0.68	0.78
Met	0.15	0.65	0.19	0.27	0.33
Phe	0.32	2.35	0.41	0.57	0.67
Thr	0.23	1.78	0.73	0.50	0.59
Trp	0.06	0.67	0.22	0.14	0.21
Val	0.34	2.41	0.67	0.76	0.90
Total	2.91	21.43	5.64	5.78	6.90
Dispensable AA, %					
Ala	0.50	1.97	0.55	0.81	0.97
Asp	0.44	5.28	1.17	1.19	1.41
Cys	0.15	0.64	0.24	0.28	0.32
Glu	1.22	8.13	1.88	1.67	2.12
Gly	0.28	1.95	0.29	0.73	0.87
Pro	0.57	2.19	0.63	0.54	0.66
Ser	0.31	1.99	0.57	0.51	0.61
Tyr	0.31	1.99	0.57	0.33	0.44
Total	3.78	24.14	5.90	6.06	7.40
All AA	2.91	21.43	5.64	5.78	6.90

[1]AEE = acid hydrolyzed ether extract.

Diets and Feeding

Defatted rice bran was purchased from Riceland Foods (Stuttgart, AR), FFRB was sourced from RiceBran Technologies (Scottsdale, AZ), whey powder was purchased from Associate Milk Producers (New Ulm, MN), and corn and soybean meal were sourced from University of Illinois Feed Mill (Champaign, IL; Table 1). A basal diet containing corn, soybean meal, and whey powder and 6 diets containing corn, soybean meal, whey powder, and 10, 20, or 30% FFRB or 10, 20, or 30% DFRB were used (Tables 2 and 3). All diets were formulated to be equal in concentrations of standardized ileal digestible indispensable AA and met or exceeded requirements for vitamins and minerals

Table 2. Ingredient composition of experimental diets containing full fat rice bran (FFRB) or defatted rice bran (DFRB)

	Diet[1,2]						
		FFRB			DFRB		
Item	Basal	10%	20%	30%	10%	20%	30%
Ground corn	52.55	44.25	35.75	27.25	44.30	35.85	27.35
Soybean meal	30.50	29.00	27.5	26.00	29.00	27.50	26.00
Whey powder	10.00	10.00	10.00	10.00	10.00	10.00	10.00
FFRB	–	10.00	20.00	30.00	–	–	–
DFRB	–	–	–	–	10.0	20.0	30.0
Choice white grease	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Enzyme premix[3]	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	1.48	1.47	1.47	1.46	1.45	1.42	1.43
Dicalcium phosphate	0.17	–	–	–	–	–	–
L-Lys HCl	0.35	0.35	0.35	0.35	0.34	0.33	0.32
DL-Met	0.10	0.10	0.10	0.10	0.09	0.09	0.09
L-Thr	0.10	0.08	0.08	0.09	0.07	0.06	0.06
Sodium chloride	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Vitamin–mineral premix[4]	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1]Two identical diets with the same ingredient composition were formulated. One of these diets contained no microbial xylanase, but the other diet contained xylanase.

[2]All diets were formulated to contain 1.26% standardized ileal digestible Lys.

[3]The enzyme premix contained either phytase (Quantum Blue [5,000 units/g]; AB Vista, Marlborough, UK) or phytase and xylanase (Econase XT-25 [160,000 units/g]; AB Vista) mixed with corn. The mixture was formulated to provide 1,500 units of phytase/kg of complete feed in all diets and 16,000 units of xylanase/kg of complete feed in all xylanase-containing diets.

[4]The vitamin–micromineral premix provided the following quantities of vitamins and microminerals per kilogram of complete diet: 11,136 IU vitamin A as retinyl acetate, 2,208 IU vitamin D_3 as cholecalciferol, 66 IU vitamin E as DL-alpha tocopheryl acetate, 1.42 mg vitamin K as menadione dimethylprimidinol bisulfite, 0.24 mg thiamin as thiamine mononitrate, 6.59 mg riboflavin, 0.24 mg pyridoxine as pyridoxine hydrochloride, 0.03 mg vitamin B_{12}, 23.5 mg d-pantothenic acid as d-calcium pantothenate, 44.1 mg niacin, 1.59 mg folic acid, 0.44 mg biotin, 20 mg Cu as copper sulfate and copper chloride, 126 mg Fe as ferrous sulfate; I, 1.26 mg as ethylenediamine dihydriodide, 60.2 mg Mn as manganese sulfate, 0.3 mg Se as sodium selenite and selenium yeast, and 125.1 mg Zn as zinc sulfate.

for 9- to 25-kg weanling pigs (NRC, 2012). All diets also contained 1,500 units/kg of microbial phytase (Quantum Blue; AB Vista, Marlborough, UK). Seven additional diets that were similar to the initial 7 diets with the exception that they also contained 16,000 units/kg of microbial xylanase (Econase XT-25; AB Vista) were also formulated. Therefore, a total of 14 diets were used. Pigs were fed experimental diets for 23 d and feed was provided on an ad libitum basis and water was also available at all times. Pig weights were recorded at the start of the experiment and on the last day of the experiment. The amount of feed provided to each pen was recorded daily and the amount of feed left in the feeder was recorded on the last day of the experiment to calculate total feed disappearance for each pen.

Blood Collection and Analysis

At the last day of the experiment, the pig in each pen with a BW that was closest to the pen average was identified and 2 blood samples were collected from the jugular vein of this pig. One sample was collected in a vacutainer without EDTA and the other sample was collected into a vacutainer containing EDTA. All samples were centrifuged at 1,500 × *g* at 4°C for 15 min to collect plasma and serum. All samples were then stored at −20°C until analyzed.

Tumor necrosis factor-α (**TNF-α**), IgA, and peptide YY (**PYY**) were measured in plasma samples using ELISA kits according to the recommendations from the manufacturer (R&D Systems, Inc., Minneapolis, MN; Bethyl Laboratories, Inc., Montgomery, TX; and MyBioSource, Inc., San Diego, CA, respectively). All samples were analyzed in duplicate. Serum samples were analyzed for blood urea nitrogen (**BUN**), albumin, and total protein using a Beckman Coulter Clinical Chemistry AU analyzer (Beckman Coulter, Inc., Brea, CA).

Analyses of Ingredients and Diets

Diets and ingredients were analyzed for DM (method 930.15; AOAC, 2007) and ash (method 942.05; AOAC, 2007), and GE was analyzed on an isoperibol bomb calorimeter (model 6300; Parr Instruments,

Table 3. Analyzed nutrient composition and physical characteristics of experimental diets containing full fat rice bran (FFRB) or defatted rice bran (DFRB)[1]

	Diet						
		FFRB			DFRB		
Item	Basal	10%	20%	30%	10%	20%	30%
GE, kcal/kg	4,026	4,151	4,239	4,366	4,053	4,059	4,033
ME,[2] kcal/kg	3,407	3,376	3,338	3,299	3,286	3,158	3,028
DM, %	87.65	88.32	89.09	90.02	88.06	88.31	88.57
CP,%	19.51	19.56	20.05	20.66	20.39	21.11	20.33
AEE,[3] %	4.54	6.57	8.59	10.13	6.23	6.18	5.86
Ash, %	5.46	5.90	6.03	6.84	6.02	7.06	8.07
Starch, %	31.91	28.36	25.12	21.60	25.14	25.01	23.53
ADF,%	2.64	3.60	4.21	5.48	3.55	4.73	4.98
NDF,%	6.13	6.97	8.45	9.66	7.52	8.81	10.10
Ca, %	0.87	0.80	0.80	0.79	0.96	1.11	1.20
P, %	0.45	0.60	0.77	0.96	0.64	0.85	1.00
STTD[4] P	0.33	0.35	0.41	0.46	0.38	0.51	0.61
Phytase activity, FTU[5]/kg	1,700	1,640	1,650	1,705	1,800	1,965	2,095
Xylanase activity, BXU[6]/kg	22,800	21,900	21,500	21,500	22,700	22,100	20,400
Indispensable AA, %							
Arg	1.26	1.28	1.35	1.35	1.31	1.37	1.41
His	0.51	0.51	0.53	0.52	0.52	0.53	03.54
Ile	0.88	0.87	0.90	0.87	0.88	0.90	0.87
Leu	1.68	1.63	1.63	1.58	1.64	1.67	1.62
Lys	1.38	1.37	1.40	1.39	1.38	1.40	1.39
Met	0.37	0.37	0.40	0.38	0.37	0.38	0.38
Phe	0.95	0.94	0.97	0.93	0.95	0.98	0.97
Thr	0.83	0.82	0.82	0.82	0.79	0.81	0.83
Trp	0.24	0.25	0.26	0.24	0.25	0.25	0.26
Val	0.94	0.94	1.00	0.98	0.97	1.01	1.03
Total	9.06	8.96	9.25	9.04	9.04	8.80	9.33
Dispensable AA, %							
Ala	0.94	9.94	0.98	0.96	0.96	1.00	1.01
Asp	1.99	1.97	2.05	1.99	1.99	2.05	2.04
Cys	0.3	0.31	0.32	0.32	0.31	0.32	0.32
Glu	3.42	3.33	3.39	3.22	3.35	3.41	3.32
Gly	0.78	0.80	0.85	0.85	0.81	0.86	0.88
Pro	1.05	1.03	1.04	0.99	1.03	1.02	1.02
Ser	0.82	0.83	0.82	0.80	0.80	0.85	0.88
Tyr	0.61	0.61	0.63	0.61	0.63	0.64	0.63
Total	9.62	9.51	9.74	9.43	9.55	9.82	9.77
All AA	18.68	18.47	18.99	18.46	18.59	18.62	19.09
Physical characteristics							
Loose bulk density, g/L	654	628	615	576	642	633	642
Water binding capacity	1.28	1.31	1.34	1.20	1.36	1.35	1.52

[1]Average of analyzed values of diets without and with xylanase.

[2]Values for ME were calculated rather than analyzed (NRC, 2012).

[3]AEE = acid hydrolyzed ether extract.

[4]STTD = standardized total tract digestible. These values were calculated (NRC, 2012; Casas and Stein, 2015) rather than analyzed.

[5]FTU = phytase units.

[6]BXU = xylanase units. Values are indicated only for the 7 diets in which microbial xylanase had been added.

Moline, IL) using benzoic acid as the standard for calibration. Crude protein was analyzed by combustion (method 990.03; AOAC, 2007) using an Elementar Rapid N-cube Protein/Nitrogen apparatus (Elementar Americas Inc., Mt. Laurel, NJ) and acid hydrolyzed ether extract (**AEE**) was analyzed using the acid hydrolysis filter bag technique (Ankom HCl Hydrolysis System; Ankom Technology, Macedon, NY) followed by fat extraction (Ankom XT15 Extractor; Ankom Technology). Concentrations of ADF and NDF were

Table 4. Growth performance of pigs fed diets containing full fat rice bran (FFRB) or defatted rice bran (DFRB)[1]

	Diets								*P*-value				
		FFRB			DFRB				FFBR		DFRB		FFRB vs.
Item	Basal	10%	20%	30%	10%	20%	30%	SEM	Linear	Quad[2]	Linear	Quad[2]	DFRB
Initial BW, kg	9.90	9.93	9.82	9.92	9.97	9.95	9.84	0.330	0.950	0.887	0.856	0.727	0.879
Final BW, kg	20.76	21.27	20.46	19.99	21.25	21.08	20.33	0.530	0.122	0.282	0.465	0.172	0.393
ADFI, kg	0.809	0.799	0.748	0.712	0.830	0.797	0.772	0.032	<0.001	0.472	0.082	0.206	0.002
ME intake, kcal/d	2,756	2,700	2,498	2,351	2,728	2,519	2,340	105.46	<0.001	0.440	<0.001	0.204	0.801
ADG, kg	0.517	0.539	0.506	0.479	0.537	0.530	0.499	0.017	0.006	0.038	0.254	0.034	0.164
G:F	0.643	0.676	0.682	0.675	0.649	0.671	0.648	0.031	0.013	0.028	0.367	0.114	0.003

[1]Data are least squares means of 16 observations for all diets and values are the average for diets without and with microbial xylanase.

[2]Quad = quadratic effect.

analyzed using Ankom Technology method 12 and 13, respectively (Ankom 2000 Fiber Analyzer; Ankom Technology). Ingredients and diets were also analyzed for Ca and P using inductively coupled plasma spectroscopy (method 985.01 A, B, and C; AOAC, 2007) and for starch (method 979.10; AOAC, 2007) and AA (method 982.30 E (a, b, c); AOAC, 2007). Phytase activity and xylanase activity in all diets were analyzed by ELISA methods using Quantiplate kits for Quantum Blue (ESC Standard Analytical Method SAM099; AB Vista) and Quantiplate kits for Econase XT (ESC Standard SAM 115; AB Vista), respectively. Bulk density was determined as previously described by Cromwell et al. (2000) and water binding capacity was measured as described by Robertson et al. (2000).

Calculations and Statistical Analysis

Data were summarized to calculate ADG, ADFI, and G:F. Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) with a randomized complete block design in a 2 × 2 × 3 factorial arrangement. The main effects in the initial model were xylanase, ingredient, inclusion level of DFFB or FFRB, and the interactions between ingredient, xylanase, and inclusion levels. However, there were no significant effects of xylanase and no interactions between xylanase and ingredient or inclusion level; therefore, xylanase and the interactions between xylanase and ingredient were removed and the final model included only diet as the main effect. Outliers and normality of data among treatments were tested using the UNIVARIATE procedure. Contrast statements were used to determine the effects of FFRB and DFRB; the linear and quadratic effects of inclusion level of FFRB or DFRB on all response variables were also analyzed using contrast statements. The pen was the experimental unit for all analyses and an α value of 0.05 was used to assess significance among dietary treatments.

RESULTS

Diet Composition

The GE of the diets containing FFRB was between 4,151 and 4,366 kcal/kg, whereas the GE in diets containing DFRB was between 4,033 and 4,059 kcal/kg. All diets contained approximately 20% CP and 1.38% Lys (Table 3). Diets containing FFRB contained between 6.57 and 10.13% AEE, but diets with DFBR contained approximately 6% AEE. The content of ADF increased from approximately 3% in the basal diet to 5 to 6% as FFRB or DFRB increased in the diets. The analyzed concentration of Ca in diets with FFRB was 0.8%, whereas in diets containing DFRB, analyzed Ca varied between 0.96 to 1.2%, and the analyzed concentration of P increased as the inclusion of FFRB and DFRB increased in the diets. The analyzed phytase activity in experimental diets was between 1,320 and 2,470 phytase units/kg. Xylanase activity was not detected in diets without xylanase, whereas in diets with xylanase, values were between 20,400 and 22,800 xylanase units/kg.

Effects of Rice Bran

Initial and final BW were not affected by the inclusion of FFRB or DFRB in the diets (Table 4). However, ADFI linearly decreased ($P < 0.05$) as inclusion of FFRB increased in the diets and there was a tendency for reduced ADFI as the concentration of DFRB increased in the diets (linear, $P = 0.08$). Pigs fed diets containing DFRB had greater ADFI ($P < 0.05$) than pigs fed diets containing FFRB. Intake of ME linearly decreased ($P < 0.05$) as the inclusion of FFRB and DFRB increased in the diets. The ADG increased and then decreased as increasing concentrations of FFRB were included in the diets (quadratic, $P < 0.05$), and this was also the case when the concentrations of DFRB increased in the diets (quadratic, $P < 0.05$). The G:F was not affected by the inclusion of DFRB but increased (quadratic, $P < 0.05$) as the inclusion of FFRB increased. The G:F was

Table 5. Blood urea nitrogen (BUN), total protein, and albumin in serum and tumor necrosis factor-α (TNF-α), IgA, and peptide YY (PYY) in plasma of weanling pigs fed diets containing full fat rice bran (FFRB) or defatted rice bran (DFRB)[1]

	Diets								*P*-value				
		FFRB			DFRB				FFBR		DFRB		FFRB vs.
Item	Basal	10%	20%	30%	10%	20%	30%	SEM	Linear	Quad[2]	Linear	Quad[2]	DFRB
BUN, mg/dL	9.20	7.37	6.50	6.25	7.25	8.37	6.93	0.520	<0.001	0.107	0.014	0.589	0.052
Total protein, g/dL	5.11	5.16	4.99	5.09	5.15	5.13	5.20	0.095	0.512	0.769	0.566	0.854	0.269
Albumin, g/dL	2.85	2.95	2.83	2.93	2.93	3.02	2.88	2.95	0.688	1.000	0.561	0.446	0.361
TNF-α, pg/mL	142.0	131.8	122.6	113.5	113.8	132.8	140.9	16.50	0.088	0.962	0.777	0.144	0.516
IgA, mg/mL	1.28	1.29	1.21	1.27	1.54	1.06	1.23	0.156	0.840	0.849	0.201	0.651	0.838
PYY, ng/mL	2.84	2.85	2.65	2.29	2.50	2.36	2.41	0.463	0.075	0.422	0.172	0.398	0.365

[1]Data are least squares means of 16 observations for all diets and values are the average for diets without and with microbial xylanase.

[2]Quad = quadratic effect.

greater ($P < 0.01$) in pigs fed diets containing FFRB than in pigs fed diets containing DFRB.

The concentration of BUN linearly decreased ($P < 0.05$) when pigs were fed diets containing increasing levels of FFRB or DFRB and there was a tendency ($P < 0.06$) for pigs fed FFRB to have less BUN than pigs fed DFRB (Table 5). Concentrations of TNF-α were between 105.5 and 163.0 ng/mL and there was a tendency for the concentration of TNF-α to linearly decrease ($P < 0.09$) as the inclusion of FFRB increased in the diet, but that was not the case when DFRB increased in the diets. Concentrations of total protein, albumin, and IgA were not affected by FFRB or DFRB. Concentrations of PYY were between 2.29 and 2.84 ng/mL and there was a tendency for a reduced concentration of PYY in plasma (linear, $P = 0.075$) as the inclusion of FFRB increased in the diets, but increasing concentrations of DFRB did not affect the concentration of PYY.

Effects of Microbial Xylanase

There were no effects of the addition of microbial xylanase on any of the growth performance data that were calculated in this experiment (Table 6). Likewise, addition of microbial xylanase to the diets did not influence BUN or other protein parameters in the blood or concentrations of TNF-α, IgA, or PYY.

DISCUSSION

The analyzed concentration of CP and AA in FFRB and DFRB agree with previous reports (Sauvant et al., 2004; NRC, 2012; Stein et al., 2016). The concentrations of NDF, starch, and AEE in FFRB used in this experiment were 15.2, 21.9, and 19.5%, respectively, whereas the values reported by the NRC (2012) are 26.3, 27.0, and 19.5%, respectively. Likewise, the concentrations of these nutrients in DFRB were 18.1, 18.6, and 7.1% and the values reported by the NRC (2012) are 23.56, 26.25, and 3.57%, respectively. The differences in the composition of ingredients were reflected in the nutritional composition of the diets in which analyzed values for NDF were lower than calculated and AEE values were greater than calculated values from the NRC (2012). The analyzed concentration of Ca in FFRB was 0.04%, which is less than reported by Sauvant et al. (2004) and the NRC (2012) but agrees with the values reported by Casas and Stein (2015). In contrast, the concentration of Ca in DFRB used in this experiment was greater than previous values. The high concentration of Ca in DFRB also was reflected in the analyzed composition of the diets. The variation in the composition of these coproducts may be a result of differences among rice mills in the milling process in which some fraction of the hulls and varying proportions of starch may be included in the rice bran. The concentration of P in the diets also increased as FFRB or DFRB increased in the diets, which is a consequence of the high concentrations of P in these ingredients and, therefore, something that was expected because FFRB and DFRB have very high concentrations of P (NRC, 2012).

The reason pigs fed diets containing DFRB had greater ADFI than pigs fed diets containing FFRB is probably that diets containing DFRB had reduced concentrations of ME compared with diets containing FFRB. Similar results were observed in growing pigs from 19 to 45 kg fed diets containing DFRB (Warren and Farrell, 1990).

The quadratic response to ADG resulting from inclusion of FFRB or DFRB indicates that at least 20% FFRB or DFRB may be included in the diets for weanling pigs without reducing ADG of pigs. This observation is in agreement with results of previous experiments, in which inclusion of 10% FFRB or 20% DFRB did not affect ADG of pigs from 5 to 10 kg or from 19 to 45 kg, respectively (Warren and Farrell, 1990; Herfel et al., 2013).

The quadratic increase in the G:F that was observed as FFRB increased in diets is a reflection of

Table 6. Effects of microbial xylanase on growth performance and blood characteristics of weanling pigs fed diets containing full fat rice bran or defatted rice bran without or with xylanse[1]

Item	Without xylanase	With xylanase	SEM	*P*-value
Growth performance				
Initial BW, kg	9.92	9.89	0.252	0.902
Final BW, kg	20.68	20.79	0.369	0.759
ADFI, kg	0.777	0.785	0.028	0.587
ME intake, kcal/d	2,542	2,570	94.20	0.600
ADG, kg	0.512	0.518	0.014	0.523
G:F	0.662	0.664	0.030	0.808
Blood characteristics				
Blood urea N, mg/dL	7.48	4.33	0.305	0.739
Total protein, g/dL	5.15	5.09	0.062	0.342
Albumin, g/dL	2.91	2.93	0.058	0.710
Tumor necrosis factor-α, pg/mL	132.04	124.43	12.80	0.417
IgA, mg/mL	1.33	1.20	0.116	0.130
Peptide YY, ng/mL	2.62	2.50	0.423	0.457

[1]Data are least squares means of 56 observations per treatment.

the greater concentration of ME in FFRB than in the basal diet. The greater G:F observed in pigs fed diets containing FFRB compared with DFRB is also a consequence of the greater ME in FFRB compared with DFRB (Casas and Stein, 2016). However, the G:F was not affected by inclusion level of DFRB, which concurs with results reported by Warren and Farrell (1990). This observation indicates that the ME in DFRB may have been underestimated because if the ME in diets containing DFRB were reduced compared with the basal diet, the G:F also should have been reduced.

The relatively high concentration of NDF in FFRB and DFRB is believed to be one of the main factors that restrict the use of these ingredients in diets for weanling pigs. Approximately 42% of NSP in FFRB are insoluble noncellulosic polysaccharides that mainly consist of arabinoxylans (Ngoc et al., 2012). Xylanases have been used to improve the digestibility of energy and nutrients in coproducts from wheat that also contain arabinoxylans (Nortey et al., 2007; Woyengo et al., 2008), but data for effects of xylanase on growth performance of pigs fed diets containing rice bran have not been reported. The lack of an effect of xylanase on growth performance of the pigs that was observed in this experiment may be a consequence of too-low inclusion rates of FFRB and DFRB and, therefore, not enough substrate for the enzyme. Likewise, it is possible that the energy released by microbial xylanase was not used with the same efficiency as that release by hydrolysis of other nutrients because xylanase may only hydrolyze the xylose backbone of the arabino-xylose molecule, and energy would then be obtained only via microbial fermentation.

The efficiency of utilization of N in pigs may be estimated by measuring BUN (Kohn et al., 2005). The linear reduction in the concentration of BUN that was observed as FFRB and DFRB increased in the diets may, at least partly, be a result of the decreased ADFI observed for these diets. However, the reduction in BUN also indicates that AA were better utilized in these diets and that less deamination of AA was taking place in pigs fed diets containing FFRB or DFRB compared with pigs fed the control diet. Concentrations of total protein and albumin were within the normal physiological ranges (Tumbleson and Kalish, 1972), and the lack of differences among treatments indicates that FFRB and DFRB did not change serum protein concentration.

Results of previous research have indicated that rice bran may improve the immune response and increase systemic and intestinal concentrations of IgA in mice, and it was hypothesized that rice bran may act as a substrate for commensal bacteria in the intestine (Henderson et al., 2012). Similar effects were observed in gnotobiotic pigs that were infected with rotavirus (Yang et al., 2014). However, in the present experiment, no differences were observed in the concentrations of IgA in response to inclusion of FFRB or DFRB. The reason for this observation may be that there were not enough immunological stimuli to induce changes in plasma concentration of IgA, because pigs used in this experiment were of high health status.

Concentration of TNF-α usually increases after infections or injuries in different tissues of the animal, and high concentrations of TNF-α may induce inflammatory responses that may reduce ADFI (Langhans and Hrupka, 1999). The tendency for decreasing concentrations of TNF-α in plasma observed in pigs fed diets with increasing concentrations of FFRB indicates a potential for reducing inflammatory responses in the intestine by including FFRB in the diets, which

concurs with the lack of changes in the concentrations of IgA. However, additional research is needed to determine the response to FFRB in pigs that are kept in environments with greater immunological challenges. Research is also needed to identify the components in FFRB that may impact immune responses in pigs.

Peptide YY is synthesized in the distal portion of the small intestine in response to neural or nutritional stimuli and functions to regulate feed intake and homeostasis of energy (Ueno et al., 2008). Increasing energy intake may induce greater concentrations of PYY in humans (Ito et al., 2006). Concentrations of PYY in plasma of pigs allowed ad libitum intake of feed were 2.2 ± 0.2 ng/mL and values did not change during the day–night cycle (Ito et al., 2006). Concentrations of PYY in plasma observed in this experiment were in agreement with values previously reported, and the tendency for a linear decrease that was observed as the concentration of FFRB increased in the diets is likely a result of the reduction in ADFI of pigs fed diets containing FFRB.

The lack of a response to the microbial xylanase in plasma concentrations of IgA, TNF-α, and PYY was expected because of the lack of response in growth performance. However, it is possible that a different response would be observed if pigs of a lower health status were used, but research to confirm this hypothesis has not been reported.

In conclusion, increased inclusion of FFRB and DFRB in diets fed to weanling pigs decreased the ADFI and improved G:F in pigs fed FFRB. Pigs fed diets containing FFRB also had a greater G:F than pigs fed diets containing DFRB, and ADG quadratically increased, with the greatest values observed if 10 to 20% FFRB or DFRB was included in the diets. Concentrations of TNF-α in pigs fed diets containing FFRB had a tendency to decrease, which may indicate a potential probiotic effect of FFRB. Concentrations of PYY tended to decrease as the concentration of FFRB increased in the diets, but there was no effect of inclusion of DFRB on concentration of PYY, indicating that the energy status of the pigs was not changed by DFRB. Concentrations of BUN decreased if FFRB or DFRB was included in the diets, indicating a better balance of AA in these diets compared with the requirements of the pigs. There was no effect of addition of microbial xylanase to diets containing FFRB or DFRB on any of the variables tested.

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