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Diet Modification to Reduce Fecal Excretion of Nitrogen and Phosphorus in Growing-Finishing Pigs

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ABSTRACT

An experiment was conducted to determine whether brewers rice can replace all corn in diets for swine and reduce fecal excretion of Nitrogen (N) and Phosphorus (P) without compromising performance and carcass quality of growing-finishing pigs. Sixteen Yorkshire x Duroc x Hampshire crosses (BW = 77±2.5 kg) were randomly assigned to either corn/soybean meal (CSM; control) or brewers rice/soybean meal (RSM) diet. Both diets were formulated to contain 14% CP. The RSM pigs had a greater reduction ($p<0.001$) in daily fecal loss of N (0.007 Vs. 0.011 kg pig^{-1}) and P (0.007 Vs. 0.008 kg pig^{-1}), lower ($p<0.001$) fecal output (0.171 Vs. 0.322 kg pig^{-1}), than CSM pigs. Compared with CSM pigs, RSM pigs gained faster (0.712 Vs. 0.581 kg pig^{-1} per day; $p<0.01$) and had better gain to feed ratio (0.30 Vs. 0.25; $p<0.01$). Furthermore, RSM pigs had greater ($p<0.001$) Apparent Total Tract Digestibility (ATTD; 91.5 Vs. 84.1%). Diet did not ($p>0.10$) affect carcass yield and Loin Eye Area (LEA), however, RSM pigs tended ($p<0.10$) to lay more back fat than CSM pigs. In conclusion, brewers rice can replace all corn in diets for growing-finishing pigs, reduce fecal excretion of N and P, increase pig performance with no effect on carcass quality. Consequently, feeding brewers rice instead of corn may help reduce environmental pollution attributed to excessive fecal excretion of N and P in growing-finishing pigs.

Keywords: Diet Modification, Fecal Nitrogen, Fecal Phosphorus, Animal Performance, Carcass Quality, Growing-Finishing Pigs

1. INTRODUCTION

Swine diets are formulated and balanced to meet daily animal requirements for different nutrients. Diets should be balanced to attain optimal use and minimize fecal excretion of dietary nutrients. Some of the nutrients excreted in swine manure are harmful to the environment. Nitrogen (N) and Phosphorus (P) significantly contribute to environmental pollution although other minerals such as calcium, potassium, copper, zinc, cadmium and lead are also hazardous (Jongbloed and Lenis, 1998). Not all nutrients supplied in the feed are absorbed, athough some are utilized less efficiently because they exceed the amounts needed by the animal (Torrallardona, 1999). Usually only 20 to 50% of N and 20 to 60% of P consumed is retained in the body; the rest is excreted in urine and feces (Pee-Schwering *et al*., 1999) with majority of the excretion occuring through the feces.

Safe disposal of manure with minimum effect on the environment is a major problem facing intensive swine production. Manure generated this way is usually applied in crop and pasture fields in place of synthetic fertilizers. However, excessive manure application may result in mineral overload in the soil and cause an imbalance between soil availability and plant use to meet requirements (Aarnink and Verstegen, 2007). Consequently, excessive amounts of N and P accumulate

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in the soil and this may cause an overload problem for the environment. Furthermore, surplus N in manure leaches into ground and surface waters resulting in high nitrate levels in ground water whereas surplus P through runoff and erosion can cause eutrophication of surface water. Modification of animal diets to include only the amount of N and P that the animal needs has shown potential to reduce the excretion of N and P (Aarnink and Verstegen, 2007; Cole *et al*., 2003; Sutton *et al*., 1999). Literature is lacking on the effect of replacing all corn with brewers rice in diets for growing-finishing pigs on animal performance and carcass quality.

Our research focused on reducing fecal loss of N and P in growing-finishing pigs because this is the stage when amounts of manure excreted are at their highest levels because of the large number and size of pigs raised within this class. Thus, we hypothesized that diet modification that includes the select use of certain energy, N and P sources will increase Apparent Total Tract Digestibility (ATTD) of nutrients and reduce fecal output and loss of N and P in the feces without effect on performance and carcass quality of growing-finishing pigs. Consequently, the objectives of this study were to determine the effect of diet modification on; (1) fecal excretion of N and P and (2) animal performance and carcass quality of growing-finishing pigs.

2. MATERIALS AND METHODS

This study was conducted at the University of Arkansas Pine Bluff (UAPB), Pine Bluff Farm, in between March 15, 2012 and April 15, 2012 and lasted 32 days.

2.1. Experimental Design, Housing and Animals

Growing-finishing pigs were randomly assigned to diets based on body weight and sex. There were two diet treatments in this experiment, replicated four times, for a total of eight pens. There were two animals per replicate for a total of sixteen animals. The animals were housed in semi-open concrete floor pens each measuring 2.13×6.26 m (2.13×2.13 m portion is under roof).

Experimental animals were managed to meet the recommendations of the UAPB Institutional Animal Care and Use Committee. Animals used in this experiment were approximately ¾ Yorkshire x ⅛ Duroc x ⅛ Hampshire crosses. Average Body Weight (BW) of the pigs on day 0 of the study was 77±2.5 kg. All animals used in this study were born and raised on the UAPB Farm. Prior to the animals being placed on the study, they were housed together on a concrete-floor growing unit with similar design of outside and inside pens. During their growing phase, the animals were fed a corn based commercial grower diet. The pigs were a mixed group of barrows and gilts. The pigs stayed in their respective pens throughout the experimental period except when they were removed for weighing and other data collections. There was no death, sickness or disease among these pigs during the experimental period.

2.2. Diets

All diets were mixed at the UAPB Farm. Most of the ingredients used in mixing the experimental diets were sourced locally. Corn, brewers rice and alfalfa pellets were ground before mixing to facilitate a homogenous feed mixture and also to increase their use.The treatment diets were: (1) Corn/Soybean Meal (CSM; control); and (2) Brewers Rice/Soybean Meal (RSM). All diets were formulated to contain 14% CP. Phosphorus level was approximately the same across diets. Feed was weighed and fed manually to the animals daily at 0900 h. Daily feed amounts offered were based on the daily nutrient requirements for growing-finishing pigs following the National Research Council (NRC) recommendations (NRC, 2012). Animals were limit fed at 2.7% of BW on a DM basis. Feed intake at this level was calculated to supply adequate nutrients to support maintenance and growth i.e., Average Daily Gain (ADG). In feed restriction, we were interested in minimizing loss of N and P in the feces by lowering intake while not compromising animal performance. The feed amounts were adjusted midway through the experimental period, to match changing animal needs due to increased growth. Drinking water was provided at all times via wall mounted nipple drinkers. Soybean meal was used as the main protein source (**Table 1**).

2.3. Variables Measured

Variables determined included: ADG, ATTD, feed N and P, fecal DM output, fecal N and P, gain to feed ratio (G:F), cost/kg of ADG, Back Fat Thickness (BFT), carcass yield, Loin Eye Area (LEA) and fat depth. To determine ADG, animals were weighed at the start (day 0), middle (day 15) and end (day 32). The ATTD of dietary N and P was the calculated percent difference between intake N and P and fecal N and P, on a DM basis.

Table 1. Composition of experimental diets

Item	Experimental Diet[1] CSM	RSM
Brewers rice, %	-	76.80
Corn, dented yellow, %	78.20	-
Soybean meal, %	10.00	13.60
Alfalfa pellets, %	8.15	5.60
Dried distillers brewer's yeast, %	-	-
Dicalcium phosphate, %	2.45	2.15
Limestone, %	0.75	1.80
Salt, %	0.20	0.20
Mineral/vitamin premix[2], %	0.25	0.25
Nutrient composition (calculated)		
ME, kcal/kg	3018.00	2730.00
CP, %	14.03	14.03
P, %	0.79	0.75
Ca, %	0.99	0.90
Lys, %	0.56	0.76
Nutrient composition (analyzed)		
N, %	1.86	2.33
P, %	0.60	0.86
NDF, %	10.50	2.73
ADF, %	4.94	2.85
Ash, %	5.63	5.70

[1]Treatments: CSM = corn/soybean meal; RSM = brewers rice/soybean meal; [2]Mineral/vitamin premix provided per kilogram: iron, 180 ppm; zinc, 180 ppm; manganese, 37 ppm; copper, 75 ppm; iodine, 2.5 ppm; selenium, 1.5 ppm; vitamin A, 15,000 IU; vitamin D_3, 2,500 IU; vitamin E, 60 IU; vitamin B_{12}, 62 µg; menadione, 2.5 mg; riboflavin, 13.7 mg; D-pantothenic acid, 102.5 mg

The fecal loss of N and P was calculated from average fecal output excreted during the last four days of the sampling period. Fecal DM output was determined by multiplying the average total feces collected by the DM percent of each fecal sample. Feed, fecal DM and N were analyzed according to procedures described by Horwitz (2000). Feed and fecal N was determined using the Kjeldahl method. This is a standard analytical method that is used to determine the concentration of N in a given sample. Feed and fecal samples were dried and ground to pass through a 2 mm screen using the Wiley mill (Thomas Scientific, Swedesboro, NJ). Ground samples from four sampling days were composited into one sample each. Composite fecal and feed samples were analyzed for DM, N, P, Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and ash.

Feed and fecal samples were also sent to an outside laboratory for N (verification) and P analysis. Samples for P analysis were digested in nitric acid (HNO_3) on a hot block heated to more than 60°C for up to 1½ hours depending on sample. Appearance of reddish smoke signaled that initial digestion was complete. Hydrogen Peroxide (H_2O_2) was added at this point and further digestion allowed to continue until about 5 mL of sample was left in the tube. The digested solution was diluted to bring the volume to 25 mL. The diluted sample was run through the Individually Coupled Plasma Emission Spectroscopy (ICP-AES) analyzer for final determination of P concentration.

2.4. Sampling Procedures

Experimental animals were weighed at the start (day 0), day 15 and end of the experiment (day 32). Back Fat Thickness (BFT) was measured on each experimental animal at weighing. The BFT was measured using a hand held ultra sound machine (Renco Lean Meater®, Minneapolis, MN). Gain to feed ratio (G: F) was calculated from ADG and feed DM intake values. Cost of gain was an estimate of the cost (feeds, labor) of gaining one kg of BW.

2.5. Fecal Collection and Feed Sampling

Total feces were collected within each pen during the last four days of experiment (day 29, 30, 31 and 32). The feces were collected at the same time every collection day, in numerical order starting with the same pen. All feces was gathered and placed in a bucket. The buckets were pre-weighed and marked by pen before filling them with the feces. Once the weight was determined, feces were mixed within the bucket and a sub-sample collected for laboratory analysis. The fecal sub-samples were stored in a freezer at -20°C, until further laboratory analysis. During the sampling period the pens were not allowed to be washed down. This was to ensure that everything excreted by the pigs during the sampling period was collected. Each batch of mixed feed was sampled at the end of each mixing. Sub-samples of each feed were placed in a bag and stored in a freezer at-20°C, until further lab analysis.

2.6. Carcass Yield

At the conclusion of the experiment, one pig per pen was randomly selected for slaughter at a nearby USDA inspected slaughter facility, to obtain carcass data. Carcass data determined were carcass yield, LEA and fat depth. Carcass yield was a calculated percent of carcass weight divided by pig BW at slaughter. Once the slaughter facility was finished with slaughter of the pigs and consequent carcass inspection, the carcasses were weighed and packed before being transported back to UAPB for further carcass evaluation. The 10th rib was removed to facilitate measurement of the LEA and fat depth. The LEA was determined using the loin eye grid. Fat depth was measured along the side of the 10th rib muscle.

2.7. Statistical Analysis

Data were analyzed as a randomized complete block design, with pen comprising of two pigs as the experimental unit and block based on initial pig BW. All data were subjected to Analysis of Variance (ANOVA) generated using the GLM procedures of SAS (SAS Inst. Inc., Cary, NC). The error term of pen within diet was used to test the effect of treatments on response variables (animal performance and carcass quality data). Treatment differences were considered significant at $p<0.05$. When a significant F-value for treatment means ($p< 0.05$) was observed in the ANOVA, it meant that it was compared using the least significant difference.

3. RESULTS

Compared to pigs finished on the CSM diet, pigs finished on the RSM diet gained faster (**Table 2**; $p<0.01$). Pigs finished on the RSM diet had a lower ($p<0.001$) fecal DM output compared to pigs fed on the CSM diet. Consequently, pigs fed the RSM diet had the greater ($p<0.001$) ATTD than the CSM pigs. Response to dietary P was somewhat different; pigs finished on the RSM diet had lower loss of dietary P compared to pigs fed the CSM diet (**Table 3**).

Results also showed a higher digestibility ($p<0.01$) of N and P for pigs fed the RSM diet compared to the CSM pigs.

Table 2. Effect of replacing corn with brewers rice on ADG, fecal output, apparent total tract digestibility, feed efficiency and cost of gain by growing-finishing pigs

Variable	CSM[1]	RSM	SEM	P value
BW at start, kg	74.830	78.628	2.531	>0.100
BW at end, kg	93.424	101.420	2.713	<0.010
DM intake, kg	2.029	2.029	0.000	
ADG, kg	0.581	0.712	0.041	<0.010
FO[2], kg	0.322	0.171	0.093	<0.001
ATTD[3], %	84.100	91.500	3.217	<0.001
G:F[4], kg/kg	0.286	0.351	0.014	<0.010
Cost of gain, $/kg	1.642	1.071	0.085	<0.050

[1]CSM = corn/soybean meal; RSM = brewers rice/soybean meal; [2]FO = fecal output (dry matter); [3]ATTD = apparent total tract digestibility; [4]G:F = gain to feed ratio

Table 3. Effect of replacing corn with brewers rice on intake, fecal N and P and digestibility of N and P in growing-finishing pigs

Variable	CSM[1]	RSM	SEM	P value
Intake N, kg	0.046	0.138	0.001	<0.001
Intake P, kg	0.011	0.011	0.000	>0.100
Fecal N, kg	0.011	0.007	0.001	<0.001
Fecal P, kg	0.008	0.007	0.002	<0.001
Digest N, %	76.682	87.915	2.770	<0.001
Digest P, %	27.413	39.810	3.634	<0.001

[1]CSM = corn/soybean meal; RSM = brewers rice/soybean meal

Table 4. Effect of replacing corn with brewers rice on the back fat thickness and carcass quality of growing-finishing pigs

Variable	CSM[1]	RSM	SEM	P value
BFT[2] 11, mm	8.125	8.125	0.375	>0.10
BFT[2] 12, mm	7.750	9.250	0.354	>0.10
BFT 21, mm	19.375	20.750	1.105	>0.10
BFT 22, mm	20.125	24.000	1.226	<0.05
BFT[3] 1 change, mm	-0.375	1.125	0.315	<0.10
BFT 2 change, mm	0.750	3.250	0.966	<0.10
Carcass yield, %	76.548	73.774	1.288	>0.10
LEA[4], cm^2	35.805	42.338	2.756	>0.10
Fat depth, cm	2.478	2.795	0.186	>0.10

[1]CSM = corn/soybean meal; RSM = brewers rice/soybean meal; [2]BFT 11 = back fat thickness (layer 1 period 1); BFT 12 = back fat thickness (layer 1 period 2); BFT 21 = back fat thickness (layer 2 period 1); BFT 22 = back fat thickness (layer 2 period 2); [3]BFT 1 change = 32-day fat accumulation for fat layer 1; BFT 2 change = 32-day fat accumulation for 2 fat layers; [4]LEA = loin eye area

Diet had no effect ($p>0.10$) on carcass quality i.e., carcass yield, LEA and fat depth (**Table 4**). Although diet had no effect on back fat thickness for layer 1, pigs fed the RSM diet tended ($p<0.10$) to lay more fat in layer 2 compared to the CSM pigs (**Table 4**).

4. DISCUSSION

Pigs fed the RSM diet had a greater reduction in fecal DM output probably due to a lower NDF and ADF level in the RSM diet (**Table 1**) compared to the CSM diet. Fiber content has an inverse relationship with digestibility and this probably explains why the CSM diet with higher fiber content was less digested compared with the RSM diet. Greater ATTD for the RSM diet meant that less feces was excreted compared to the CSM diet.

The significant reduction in the fecal loss of N and P may have been due to differences in ATTD and, dietary NDF and ADF. The RSM diet had a greater N and P digestibility and lower levels of NDF and ADF compared with the CSM diet. Fiber (mainly ADF) and digestibility are negatively correlated, thus, the significantly lower ADF levels in the RSM diet compared with the CSM diet probably explains the corresponding differences in animal response. Furthermore, a more favorable N to P ratio (Bjorck *et al*., 1994; French, 1973) in the RSM diet (mainly attributed to brewers rice) compared with the CSM diet (mainly attributed to corn) may have resulted in greater digestibility and lower excretion of N and P in the feces.

In addition, greater ATTD for the RSM fed pigs compared to the CSM fed pigs can be attributed to differences in the concentration of Non-Starch Polysaccharides (NSP), mainly the cell wall carbohydrates, Resistant Starch (RS) to amylase digestion and other complexes (Brown, 1996; Englyst *et al*., 1992; Gallant *et al*., 1992). The RSM diet probably had a lower amylose (Goddard *et al*., 1984), NSP and RS (Berry, 1986) concentration making the diet more digestible than the CSM diet. Regular rice contains about 20% amylose and thus less RS, compared to more than 25% for corn (Bjorck *et al*., 1994; Rooney and Pflugfelder, 1986).

A better gain to feed ratio for pigs fed the RSM diet compared with the CSM pigs may have been due to greater ADG since feed intake was the same across diets. Although intake of N and P was greater for pigs fed the RSM diet, pigs fed the CSM diet excreted more N and P in the feces, suggesting that dietary N and P were bound to NSP more in the CSM diet than in the RSM diet.

5. CONCLUSION

Brewers rice replaced all corn in diets for growing-finishing pigs without having any adverse effects on animal performance. In addition, pigs fed brewers rice based diet used N and P more efficiently as demonstrated by a greater reduction in the fecal excretion of these nutrients. Thus, brewers rice is a suitable alternative to corn for finishing pigs in regions where it is in abundant supply.

5.1. Implications

Diet modification that involved the use of brewers rice in place of corn may have resulted in greater N and P being digested. Thus, brewers rice based diets may have provided animals with highly digestible nutrients and this may have contributed to a reduction in the fecal excretion of N and P. Further research should determine the eating attributes and fat profile of carcasses harvested from pigs finished on brewers rice based diets compared to corn based diets. Future research should determine the extent of N and P bound to non-starch polysaccharises and how this affects availability of dietary N and P relative to utilization in swine.

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