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EFFECT OF GRAIN SOURCE AND DIETARY LEVEL OF OAT HULLS ON PHOSPHORUS AND CALCIUM UTILIZATION IN THE GROWING PIG[1,2]

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Summary

Three metabolism trials were conducted to determine the effect of grain source and dietary level of oat hulls on dry matter digestibility, P and Ca retention and intestinal phytase activity of growing pigs. Twenty-four crossbred pigs (39 kg) were used. Dry matter digestibilities of corn-based diets were greater (P<.01) than grain sorghum-based diets (74.7 vs 63.5%). Diets containing 10% oat hulls had lower (P<.01) dry matter digestibilities than diets containing no oat hulls (64.0 vs 74.2%). The reduction in dry matter digestibility was similar with the addition of oat hulls to the diet, regardless of the source of grain. P and Ca retentions were not affected by dietary treatments. Fecal excretion of P was higher (P<.10) for pigs fed 10% oat hulls than for those fed no oat hulls. Fecal excretion of Ca and urinary excretion of Ca and P were not affected by dietary treatment. Intestinal phytase activity was evident in all pigs, but the dietary treatments had no apparent influence on phytase production in the small intestine.

(Key Words: Grain, Fiber, Phosphorus, Calcium, Phytase, Swine.)

Introduction

Utilization of dietary fiber by growing swine is limited. High levels of fiber in the diet have been shown to inhibit growth of swine (Teague and Hanson, 1954; Hochstetler et al., 1959; Jensen et al., 1959; Moser, 1980). The depression in growth has been attributed to dilution of the energy content of the diet by the high fibrous feedstuffs (Jensen et al., 1959; Cole et al., 1967; Baird et al., 1970). Also, dietary fiber decreases apparent dry matter and nitrogen digestibility in pigs (Teague and Hanson, 1954; Keys et al., 1970; Farrell and Johnson, 1972; Kass et al., 1980).

The effect of dietary fiber on mineral availability is still under question. Dietary fiber has been shown to bind Ca and Zn in vitro (Reinhold et al., 1976; Branch et al., 1977). Addition of dietary fiber to human diets (Reinhold et al., 1976) and rat diets (Drews, 1977) has resulted in negative balances of Ca, Mg, Zn, Co and P. Drews (1977) reported that the effect of fiber on mineral balance was dependent upon the chemical composition of the fiber. Limited research has been conducted on the effect of dietary fiber on mineral utilization in swine. Although the intestinal tract of the pig contains some phytase (Spitzer and Phillips, 1945), the ability of the pig to utilize phytin P is limited (Peeler, 1972). The effect of dietary fiber on intestinal phytase activity in the pig has not been determined. The improvement in the utilization of phytin P would increase the percentage of available P in plant sources, generally thought to be low (<30%).

Therefore, the objective of the research reported herein was to determine the effects of grain source and dietary level of oat hulls on dry matter digestibility, P and Ca retention and intestinal phytase activity of growing pigs.

Experimental Procedure

Metabolism Trial. A total of 24 crossbred barrows was used in three metabolism trials. Eight pigs were assigned to each trial by weight (average initial weights 37.8, 39.3 and 40.5 kg for trials 1, 2 and 3, respectively) and randomly allotted to four treatment groups. Experimental diets (table 1) consisted of a grain

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TABLE 1. COMPOSITION OF DIETS

Ingredient	Diet 1	Diet 2	Diet 3	Diet 4
	%			
Ground grain sorghum (IFN 4-05-643)	77.85	66.92		
Ground yellow corn (IFN 4-02-992)			77.83	66.87
Soybean meal (44%) (IFN 5-04-604)	19.56	20.67	19.56	20.67
Ground oat hulls (IFN 1-03-281)		10.00		10.00
Dicalcium phosphate (IFN 6-01-080)	.18	.08	.23	.13
Limestone (IFN 6-01-080)	1.06	.98	1.03	.98
Salt (IFN 6-04-151)	.25	.25	.25	.25
Trace minerals[a]	.10	.10	.10	.10
Vitamin premix[b]	1.00	1.00	1.00	1.00
	100.00	100.00	100.00	100.00
Analyzed[c]				
Crude protein	15.8	15.8	16.0	15.2
Ca	.54	.53	.58	.55
P	.39	.36	.39	.37
NDF	15.9	23.8	14.7	18.5
ADF	4.8	7.2	2.8	6.3

[a]Contributed the following in mg/kg of diet: Zn, 200; Fe, 100; Mn, 55; Cu, 10; Co, 1; I, 1.5.

[b]Contributed the following per kilogram of diet: vitamin A, 3,300 USP units; vitamin D_3, 440 ICU; vitamin E, 22 IU; riboflavin, 2.2 mg; pantothenic acid, 13.2 mg; niacin, 17.6 mg; choline chloride, 110 mg; vitamin B_{12}, 2.2 μg; ethoxyquin, 4.4 mg; menadione sodium bisulfate, 2.2 mg. Premix was provided in a ground corn carrier.

[c]Percentage on an as-fed basis.

sorghum-soybean meal base and a corn-soybean meal each fed with 0 or 10% ground oat hulls. Diets were formulated to contain 16% crude protein, .55% Ca and .40% P. Analyses of the diets for percentage of crude protein, Ca and P are shown in table 1.

In each trial, pigs were assigned to dietary treatments and fed ad libitum for 7 d. They were then placed in circular metabolism crates for a 3-d adaptation and 5-d collection period. Pigs were fed according to body size, by the formula of body weight$^{.9}$ x 5%. Slight adjustments of this formula helped keep daily energy intakes consistent for all pigs. Pigs were fed once daily, but water was available at all times.

Total fecal collections were made daily and frozen for later analysis. The daily urine collection was acidified, measured, subsampled and frozen until analyzed. Subsamples of fecal collections from each pig were dried at 110 C for 24 h for determination of dry matter digestibility. Ca and P concentrations of the diets, feces and urine were determined by automated procedures adapted from Gitelman (1967) and Frankel et al. (1970).

Intestinal Phytase Assay. After the metabolism trial, pigs remained on dietary treatments until slaughter. The total feeding periods were 30, 21 and 34 d in trials 1, 2 and 3, respectively. At slaughter, a 15-cm segment of the duodenum was removed 10 cm distal to the attachment of the common bile duct. Each segment was trimmed to a 10 cm length, sectioned lengthwise, washed thoroughly with deionized water for removal of adhering digesta and placed on ice. After several minutes, segments were blotted dry, weighed and sectioned into small pieces, which were then placed in a test tube containing 10 ml ice-cold .2 M Tris-HCl buffer, pH 7.6, and homogenized three times in a Brinkman homogenizer for 15 s at 20-s intervals. An additional 10 ml of Tris buffer were added to the homogenate. Homogenates were filtered through two layers of cheesecloth and frozen until analyzed.

For the phytase activity assay, the homogenates were thawed and preincubated at 37 C for 20 min. The assay mixtures, consisting of 3.4 ml .2 M Tris-HCl buffer, pH 7.6; .1 ml .05 M $MgCl_2 4H_2O$; 1.0 ml sodium phytate (10 mg/ml), and .5 ml of intestinal homogenate, were then incubated for 2 h at 37 C. The reactions were stopped by the addition of 5 ml of 10% trichloracetic acid.

Levels of P liberated from the sodium phytate were determined by a separate assay. One milliliter of the final phytate mixture was diluted to 5 ml with deionized H_2O. To this, 2 ml of a molybdic reagent (1.9% sodium molybdate in 2.5 N H_2SO_4) was added and allowed to set for 2 min. Then, 1 ml of Elon reducing agent (7.5 g sodium bisulfate and 2.5 g methyl-p-amino phenolsulfate in 250 ml H_2O) was added to each tube and the color was allowed to develop for 30 min. Samples were read on a spectrophotometer[3] at 600 nm and compared to a standard P curve.

As a phytase standard, .5, 1.0, 1.5 and 2 ml of a wheat phytase solution (50.5 mg crude protein/25 ml buffer[4]) were analyzed under identical conditions. Results showed that the amount of P released from the sodium phytate was directly correlated (r = .99) to the amount of enzyme used, so the level of enzyme was assumed to be the limiting factor in the assay.

Analyses of variance were carried out on all data as described by Barr et al. (1976) and Steel and Torrie (1960).

Results and Discussion

The treatment × trial interaction was nonsignificant for all characteristics indicating that the response to the treatments was the same in all three trials. Therefore, data have been pooled across trials.

[3]Coleman Model 55 UV vis, Coleman Inst. Div. Perkin–Elmer, Oakbrook, IL.

[4]Sigma Chemical Co., St. Louis, MO.

The effects of grain source and dietary level of oat hulls on dry matter digestibility are summarized in table 2. The percentage of dry matter digested was greater ($P<.01$) for pigs fed corn-based diets than for those fed grain sorghum-based diets (74.7 vs 63.5%). The dry matter digestibility of the corn soybean meal control diet compared favorably to that of a similar limit-fed diet in the study by Kass et al. (1980). In contrast, the digestibility of the grain sorghum control diet was considerably lower than that of the corn control diet. These differences may be attributed to the higher rate of passage of grain sorghum-based diets than of corn-based diets (Thurber, 1966). Grinding of sorghum will affect its digestibility. Tanksley (1961) reported that coarse grinding of grain sorghum was preferred to fine grinding to achieve maximum performance. In this study coarse grinding merely cracked the seed coat, while corn was finely ground. More recently though, Owsley et al. (1979) suggest that digestibility of the dry matter of sorghum is improved by fine grinding.

The percentage of dry matter digested was lower ($P<.01$) for pigs fed 10% oat hulls than for pigs fed no oat hulls (64.0 vs 74.2%). The decrease in dry matter digestibility with increased level of dietary fiber agrees with the findings of Keys et al. (1970) and Kass et al. (1980). The depression in dry matter digestibility, 10 percentage units, was the same as the level of oat hulls added to the diet, 10%. This suggests that the oat hulls were poorly digested by the pig (Bell, 1960) or that the addition of dietary fiber caused an increase in the rate of passage (Maynard et al., 1979) or both. Dry

TABLE 2. EFFECT OF GRAIN SOURCE AND DIETARY LEVEL OF OAT HULLS ON DRY MATTER DIGESTIBILITY IN GROWING PIGS[a]

	Treatment				
Item	Sorghum control 1	Sorghum + 10% oat hulls 2	Corn control 3	Corn + 10% oat hulls 4	CV for criterion, %
Dry matter					
Intake, g/d	1,247	1,386	1,268	1,306	
Excreted, g/d	387	584	254	397	
Digestibility, %[bc]	69.0	58.0	79.5	69.9	18.41

[a]Average for six pigs per treatment; body weight, 39 kg.

[b]Effect of grain source ($P<.01$).

[c]Effect of fiber level ($P<.01$).

TABLE 3. EFFECT OF GRAIN SOURCE AND DIETARY LEVEL OF OAT HULLS ON P AND CA RETENTION IN GROWING SWINE[a,b]

	Treatment				
Item	Sorghum control 1	Sorghum + 10% oat hulls 2	Corn control 3	Corn + 10% oat hulls 4	CV for criterion, %
P					
Intake, g/d	5,351	5.529	5.369	5.373	
Fecal excretion, g/d[c]	3.209	3.545	3.116	3.282	9.43
Urinary excretion, g/d	.008	.008	.007	.006	55.20
Retention, g/d	2.134	1.976	2.246	2.085	18.41
Retention, %	39.9	35.7	41.8	38.8	
Ca					
Intake, g/d	7.372	7.991	7.966	8.089	
Fecal excretion, g/d	4.165	4.440	4.023	4.255	18.34
Urinary excretion, g/d	1.173	1.111	1.319	1.101	41.26
Retention, %/d	2.034	2.440	2.624	2.733	39.51
Retention, %	27.6	30.5	32.9	33.8	

[a]Average for six pigs per treatment; body weight, 39 kg.

[b]Treatment X trial interaction was nonsignificant.

[c]Effect of fiber level (P<.10).

matter digestibility of the corn-based diet plus 10% oat hulls was the same as that of pigs fed grain sorghum-based diets without oat hulls. The grain source X fiber level interaction was not significant, suggesting that dry matter digestibilities were affected similarly by the addition of oat hulls, regardless of the source of grain.

The effects of grain source and dietary level of oat hulls on P and Ca retention are shown in table 3. No significant differences in P retention were observed across the dietary treatments; however. P retention tended to be lower in pigs fed oat hulls. Fecal excretion of P was higher (P<.10) for pigs fed 10% oat hulls than for pigs fed no oat hulls. Urinary excretion was not affected by dietary treatment. The increase in P excreted in the feces and concurrent decreases in P retention support the findings of Reinhold et al. (1976), who observed that dietary fiber caused a negative P balance in adult male humans. Fecal excretion of P as a percentage of the P intake was 62.5% for pigs fed oat hulls and 59% for pigs fed no oat hulls. These results suggest that oat hulls may have bound P or increased rate of passage, or both,

TABLE 4. EFFECT OF GRAIN SOURCE AND DIETARY LEVEL OF OAT HULLS ON INTESTINAL PHYTASE ACTIVITY IN GROWING PIGS[abc]

	Treatment				
Intestinal phytase	Sorghum control 1	Sorghum + 10% oat hulls 2	Corn control 3	Corn + 10% oat hulls 4	CV for criterion, %
Phytase activity, μg P liberated$\cdot$min$^{-1}\cdot$ml homogenate^{-1}	.1523	.1698	.1710	.1536	17.81

[a]Average for six pigs per treatment.

[b]Treatment offered for 30, 21 and 34 d in trials 1, 2 and 3, respectively.

[c]Treatment X trial interaction was nonsignificant.

resulting in the absorption of less P by the pig.

Ca excretion and retention were not significantly affected by dietary treatment. The addition of oat hulls tended to increase Ca excretion in the feces but decreased urinary excretion of Ca. A slightly higher Ca retention was observed in pigs fed 10% oat hulls than in those fed no oat hulls. Although not significant, the increase in fecal calcium concentration supports the findings of Reinhold et al. (1976) and Branch et al. (1977) that dietary fiber binds Ca; however, the Ca retention data in the present study would not support these findings. Pigs fed corn retained more P (2.17 vs 2.06 g/d) and Ca (2.68 vs 2.24 g/d) than pigs fed grain sorghum, but these differences were not significant.

Dietary fiber seemed to have no significant effect on mineral utilization by the pigs. Addition of oat hulls to the diet resulted in a slight decrease in P retention, but a slight increase in Ca retention. However, positive retentions of P and Ca were observed for all pigs. This finding contrasts with negative mineral balances observed in adult humans (Reinhold et al., 1976) and young rats (Drews, 1977) fed dietary fiber. Reasons for these discrepancies are unclear. Drews (1977) reported that the effect of dietary fiber on mineral utilization is dependent on the chemical composition of the fiber. The highly fibrous Bazari bread used as a fiber source in the study by Reinhold et al. (1976) has a chemical composition different from the fiber of oat hulls. Drews (1977) fed hemicellulose, cellulose and lignin to rats and reported that the hemicellulose component was responsible for increased fecal excretion of minerals. In this study, the addition of 10% oat hulls increased the hemicellulose in the diet by only 3 percentage units, suggesting that hemicellulose content of the diet containing oat hulls may not be high enough to cause a marked change in mineral retention.

The effects of grain source and dietary levels of oat hulls on intestinal phytase activity are shown in table 4. Dietary treatment had no significant effect on intestinal phytase activity. Phytase activity tended to increase with the addition of oat hulls to the grain sorghum-based diets, but it decreased when oat hulls were included in corn-based diets. However, the grain source × fiber level interaction was not significant, probably because of the large variation among pigs. Source of grain had no effect on phytase activity. These data conflict somewhat with the findings of Schneiman and Gallaher (1980), who reported a decrease in other intestinal enzymes when solka floc was added to the diets of rats.

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