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Corn, small grains, and plant protein supplements, which are major ingredients in practical swine rations, can supply more than half of the NRC (1968) phosphorus requirement if total phosphorus values of the various ingredients are used in ration formulation. Research, mainly with poultry, has established that about one-third of the phosphorus present in plant ingredients such as corn, small grains, and soybean meal is available to non-ruminant animals (Hammond, 1964). Moore and Tyler (1955) reported that pigs can utilize considerable amounts of phytic acid because a favorable pH in the pig's stomach is conducive to continued action by plant phytases found in the dietary ingredients. Suggestions have been made that available phosphorus values of plant ingredients should be used to formulate rations for swine.

The present study was conducted to evaluate the use of available (assumed 50%) versus total phosphorus values of corn and soybean meal in meeting the phosphorus requirement for maximum body weight gain and feed efficiency, and the maintenance of hematocrit, serum calcium and inorganic phosphorus levels.

Experimental Procedure

One hundred and sixty crossbred pigs (average initial weight: 25.5, 86.0, and 117.6 lb., respectively, for trials 1, 2 and 3), involving 15 randomized blocks of pigs, based on the body weight of those pigs, were used in three similar trials. Within each block, outcome groups of pigs were formed, based on weight, sex, and litter. The two rations fed are shown in table 1. In ration 1, the phosphorus requirement was met by assuming that only 50% of the phosphorus in corn and soybean meal was available. In ration 2, the total phosphorus content of corn and soybean meal was used in calculating the phosphorus requirement. The following protein level sequence was used with both rations: 16% crude protein ration to 75 lb.; 14% from 75 to 150 lb.; and 12% from 150 lb. to termination of the trial. The calculated protein, available and total phosphorus, and calcium values are shown in table 1. Also given are the calcium-phosphorus ratios for available and total phosphorus. The available phosphorus content in ration 1 was approximately the same as the total phosphorus content in ration 2.

Pigs were housed in pens with partially slotted floors within an enclosed building. A nonpelleted feed was self-fed, and water was available at all times. Pigs were weighed, and feed consumption was determined every 2 weeks. The trials were terminated when the pigs weighed from 175 to 200 pounds. Blood samples were taken from pigs in trials 1

and 2 to determine hematocrit, serum inorganic phosphorus, and serum calcium levels by standard laboratory methods. The data were analyzed, using the analysis of variance technique.

Results and Conclusion

Average daily gains were not significantly different between groups of pigs fed the two rations in the trials, with one exception (table 2). In trial 2, pigs fed ration 2 based on total phosphorus, gained significantly faster during the first 4 weeks of the trial than pigs fed ration 1 based on available phosphorus. However, the difference was not significant for the entire period. Average daily feed intake appeared to be slightly less for pigs fed ration 2, with most of the effect evident during the latter part of the finishing period. This reduction in feed intake, with no difference in average daily gain, resulted in a slightly lower non-significant feed/gain ratio for pigs fed ration 2.

Hematocrit values in trial 1 did not differ between the two rations; however, in trial 2, pigs fed ration 2 had slightly lower ($P<.05$) values than pigs fed ration 1. There is no apparent explanation for this difference in hematocrit values. Serum calcium values did not differ between pigs fed the two rations.

Serum inorganic phosphorus levels did not differ among pigs fed the two rations, which agrees with reports by Cromwell *et al.* (1970) and Harmon *et al.* (1970). In the reports by Cromwell *et al.* (1970) and Harmon *et al.* (1970), working with 40-to 200-lb. pigs, serum inorganic phosphorus levels increased with increasing dietary levels of phosphorus up to about 0.45 to 0.54% total phosphorus, and remained essentially the same when additional phosphorus was added. There was a trend for serum inorganic phosphorus levels to decrease at the highest level of phosphorus intake (0.75%) as reported by Harmon *et al.* (1970). The level of total phosphorus in rations 1 and 2 was similar to the level in medium and high phosphorus rations used by Cromwell *et al.* (1970) and Harmon *et al.* (1970). The highest dietary calcium level (about 0.83%) used by Harmon *et al.* (1970) was much higher than that used by Cromwell *et al.* (1970) and that used in the present study.

Harmon *et al.* (1970) reported that weight gains increased with increasing dietary phosphorus, plateauing at 0.5% total phosphorus. Results from Cromwell *et al.* (1970) suggests that a phosphorus level of 0.5% from 40 to 100 lb., followed by a level of 0.4% at 205 lb., was sufficient for maximum weight gain and feed efficiency. As indicated above, the calcium level used by Cromwell *et al.* (1970) was lower than that used by Harmon *et al.* (1970). The resulting difference in the calcium to phosphorus ratios might explain the difference between the two

reports in the level of phosphorus needed for optimum growth. Results from the present study agree more with the finding of Cromwell et al. (1970).

No problems were encountered with skeletal abnormalities or with bone breakage. Cromwell et al. (1970) indicated that bone density was not improved by feeding phosphorus levels higher than 0.5 and 0.4% during the growing and finishing stages, respectively. However, results with baby pigs showed that bone development was improved by feeding them levels of calcium and phosphorus higher than those levels required for maximum weight gains and feed efficiency (Combs et al., 1962 and Miller et al., 1962, 1964). The difference between the level of calcium and the level of phosphorus needed for maximum growth and for maximum skeletal development may be less for the growing and finishing pig than for the baby pig. Cromwell et al. (1970) and Harmon et al. (1970) reported phosphorus deficiency when corn-soybean meal rations did not have some highly available phosphorus added, such as dicalcium phosphate.

If available phosphorus values are calculated (table 1) for diet 2, it can be seen that the phosphorus requirement based on available phosphorus may be no higher than 0.25 to 0.35%. A calcium to available phosphorus ratio of 2:1 would appear to be optimum where available phosphorus values are used. This finding agrees with that of Morrison (1970). The ratio of calcium to phosphorus is important, as shown by the work of Morgan et al. (1969); increasing dietary calcium without changing the dietary phosphorus increased calcium retention and decreased phosphorus retention.

These data show that the additional phosphorus, which is added when available phosphorus values are used in formulating rations to meet the phosphorus requirement, is not needed. This conclusion is supported by the fact that there were no significant differences in average daily gain, feed efficiency, serum inorganic phosphorus and serum calcium levels. It is suggested that, if available phosphorus values are to be used in ration formulation, the NRC (1968) recommended level of phosphorus must be re-examined. The phosphorus requirement will be less than is presently recommended.

Summary

Three trials using 160 crossbred pigs ranging in weight from 25 to 117 lb. initially were used to evaluate using available versus total phosphorus values of corn and soybean meal to meet the phosphorus requirement for maximum body weight-gain and feed-efficiency; also the maintenance of blood serum calcium and inorganic phosphorus levels. Two rations were used, one in which the phosphorus requirement was met by assuming that

only 50% of the phosphorus in corn and soybean meal was available, and one in which the total phosphorus values were used in calculating the phosphorus requirement. Average daily gains were not significantly different between pigs fed the two rations when the data were summarized for the entire trial. Average daily feed intake appeared to be slightly less for pigs fed the ration based on total phosphorus. This effect was more evident during the latter part of the finishing period. There was a slight but non significant lower feed/gain ratio for pigs fed the ration based on total phosphorus. Serum inorganic phosphorus and serum calcium values were not different between pigs fed the two rations. Results of this study suggest that, if available phosphorus values are used to formulate rations, then the phosphorus requirement will be less than is presently recommended by NRC (1968).

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TABLE 1. PERCENTAGE COMPOSITION OF RATIONS

Protein level	Rations[1]					
	16		14		12	
	1	2	1	2	1	2
P req. based on	Avail.	Total	Avail.	Total	Avail.	Total
P. calculated						
Available[2]	0.56	0.35	0.44	0.27	0.40	0.25
Total	0.73	0.52	0.60	0.44	0.56	0.41
Ca calculated	0.77	0.77	0.53	0.53	0.49	0.49
Ca:P_A ratio	1.38	2.20	1.20	1.96	1.23	1.96
Ca:P_T ratio	1.05	1.48	0.88	1.20	0.88	1.20
Corn	76.05	76.25	82.65	82.80	88.65	88.78
Soybean meal (44%)	20.80	20.80	15.00	15.00	9.25	9.25
Defluorinated phosphate	2.20	1.00	1.50	0.60	1.40	0.55
Limestone	---	1.00	---	0.75	---	0.72
Swine trace mineral salt[3]	0.50	0.50	0.50	0.50	0.50	0.50
Vitamin premix[4]	0.35	0.35	0.25	0.25	0.15	0.15
Antibiotic[5]	0.10	0.10	0.10	0.10	0.05	0.05

[1]The feeding schedule was: 16% to 75 lb.; 14% from 75 to 150 lb.; 12% from 150 to 220 lb.

[2]Plant phosphorus assumed to be 50% available.

[3]Contained (%): 0.8 Mn, 0.4 Fe, 0.08 Cu, 0.01 Co, 0.01 I, 1.0 Zn and 95.9 salt.

[4]Supplied (per lb. of premix): 0.6 gm riboflavin, 3.1 gm pantothenic acid, 3.1 gm niacin, 4.8 mg vitamin B_{12}, 100 gm choline chloride, 600,000 I.U. vitamin A, 100,000 I.U. vitamine D and 1,000 I.U. vitamin E.

[5]Contained 50 gm per lb. each of neomycin sulfate and terramycin.

TABLE 2. AVERAGE DAILY GAIN, FEED INTAKE, FEED EFFICIENCY, HEMATOCRIT, SERUM CALCIUM AND INORGANIC PHOSPHORUS

	Rations					
	Trial 1		Trial 2		Trial 3	
Criteria	Avail.	Total	Avail.	Total	Avail.	Total
No. of pigs	30	30	30	30	20	20
Av. initial wt., lb.	25.5	25.6	86.1	85.9	117.9	117.3
Av. final wt., lb.	180.0	174.8	199.5	200.4	202.5	200.9
Av. daily gain, lb.						
0-4 weeks	1.22	1.24	1.83	1.94*	2.08	2.12
4-8 weeks[1]	1.71	1.62	1.86	1.81	1.21	1.10
0-8 weeks[1]	1.47	1.43	1.84	1.87	1.73	1.70
8-14 weeks[1]	1.72	1.65	1.34	1.35	---	---
0-14 weeks[1]	1.58	1.53	1.79	1.82	---	---
Av. daily feed intake, lb.						
0-4 weeks	2.88	2.88	5.36	5.42	5.67	5.30
4-8 weeks[1]	5.08	4.98	6.17	5.99	5.45	4.81
0-8 weeks[1]	3.98	3.93	5.77	5.70	5.59	5.10*
8-14 weeks[1]	6.35	5.68*	6.57	6.01	---	---
0-14 weeks[1]	4.99	4.62	5.86	5.74*	---	---
Feed per gain						
0-4 weeks	2.35	2.31	2.93	2.79	2.74	2.50
4-8 weeks[1]	2.97	2.94	3.31	3.30	4.83	4.40
0-8 weeks[1]	2.67	2.63	3.14	3.05	3.25	2.99
8-14 weeks[1]	3.68	3.44	4.90	4.45	---	---
0-14 weeks[1]	3.17	3.03	3.27	3.15	---	---
Hematocrit, %						
Initial	34.69	35.40	---	---	---	---
Final	42.81	42.07	43.67	41.73*	---	---
Serum inorganic P, mg/100 ml						
Initial	8.03	8.11	---	---	---	---
Final	9.39	9.51	6.98	6.64	---	---
Serum Calcium, mg/100 ml						
Initial	11.46	10.95	---	---	----	---
Final	10.08	10.50	11.52	11.40	---	---

[1]Trial 2 - 8-10 weeks and 0-10 weeks include only three of six replications. Trial 3 - 4-6 weeks for two replicates and 4-8 weeks for two replicates.

*(P<.05)