Mineral Balance Studies with the Baby Pig:
Effects of Dietary Phosphorus Level upon
Calcium and Phosphorus Balance

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ABSTRACT Calcium and phosphorus balance studies were conducted on 29 baby
pigs receiving a synthetic milk diet containing phosphorus levels of 0.2, 0.4, 0.6,
0.7 and 0.8% with 0.8% calcium. Growth rate, food intake and mineral retention
were greatly depressed in pigs receiving 0.2% of phosphorus. Increasing dietary phosphorus levels to 0.5% resulted in increased total phosphorus retention (g) and percent
phosphorus retention. Increasing dietary phosphorus levels beyond 0.5% did not
increase phosphorus retention (g) but decreased percentage phosphorus retention. Dietary phosphorus levels below 0.5% resulted in reduced calcium retention (g)
whereas increasing dietary phosphorus levels above 0.5% did not affect calcium balance. The dietary phosphorus requirement for optimal utilization of calcium and phosphorus is therefore about 0.5%.

Mineral balance studies with animals provide information concerning mineral absorption and retention and offer a means of assessing the effects of dietary nutrients levels and other factors upon mineral utilization. Few mineral balance studies with baby pigs have been conducted. Danish (1), German (2, 3), Canadian (4) and American (5, 6) balance trials concerned with calcium and phosphorus utilization of young pigs receiving sow’s milk, sow’s milk substitutes or synthetic milk diets have been reported.

The present study was undertaken to determine the effects of dietary phosphorus level upon calcium and phosphorus utilization by the baby pig as determined by mineral balance trials and to provide supplemental information toward a more accurate determination of the dietary phosphorus requirement of the baby pig (7).

MATERIALS AND METHODS

Baby pigs used in the study were from 2 trials conducted to determine their phosphorus requirement (7). Calcium and phosphorus balance studies were conducted with pigs receiving 0.2, 0.4 or 0.6% of dietary phosphorus in the first trial, and 0.4, 0.5, 0.6, 0.7 or 0.8% of dietary phosphorus in the second trial. Casein furnished 0.2% of phosphorus in each of the diets with USP grade CaHPO₄·2H₂O supplying the additional phosphorus for the higher dietary levels. Dietary calcium level for all pigs was maintained at 0.8% by appropriate reduction of CaCO₃ when CaHPO₄·2H₂O was increased. Thus the sources of dietary calcium were CaCO₃ and CaHPO₄·2H₂O and the sources of dietary phosphorus were casein and CaHPO₄·2H₂O. All diets contained 1800 IU of vitamin D₃/kg of solids.

Pigs used in the balance studies were placed in metal metabolism cages for a 3-
to 5-day adjustment period prior to the collection period. Pigs were removed from the metabolism cage to other cages to be fed (4 times daily while fed the liquid diet or 3 times daily with dry diet) an amount of food and water which they would consume within a 5- to 10-minute period. Their mouths were wiped clean and then they were returned to the collection cages. Constant daily feed intakes were maintained throughout the remainder of the adjustment period and the 3-day collection

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period. Feces were collected separately from urine by means of a fine screen placed above the collection tray. Urine contamination was minimal because of the firm nature of the feces. In the first trial, collections were made at 2, 4 and 6 weeks of age with pigs receiving the synthetic diet as a liquid during the first 2 collections and as a dry meal in the final collection. In the second trial collections were made during the final 2 weeks (5 and 6 weeks of age) with all pigs receiving the dry meal diet. Rate of dietary consumption was depressed only in pigs receiving 0.2% of dietary phosphorus. Total dietary intakes of pigs fed other levels of dietary phosphorus were equated during simultaneous collection periods.

Total fecal collections were dried in a low temperature (70°C) convection oven, weighed, finely ground and stored in air-tight containers. Total urine collections were acidified with 6 M HCL to a pH of between 1 and 2, the volume accurately measured and 100-ml samples stored in air-tight bottles. Analyses of fecal and urine calcium and phosphorus concentrations were by modifications of the methods of Varley (8). Statistical analyses of data were performed using the multiple range test of Duncan (9).

RESULTS AND DISCUSSION

Results of balance studies conducted during the first trial are presented graphically in figures 1 and 2. Dietary intake was depressed very early in the trial in pigs receiving 0.2% of dietary phosphorus. Animals receiving the 2 higher levels of dietary phosphorus received equal food intakes. Level of dietary phosphorus had a positive effect upon calcium and phosphorus retention at each age. Daily calcium and phosphorus retention increased with age at each level of dietary phosphorus. A great increase in calcium and phosphorus retention occurred from 4 to 6 weeks of age in pigs receiving 0.4 or 0.6% of dietary phosphorus. This increased retention was primarily due to the greater intakes of calcium and phosphorus that occurred when the dietary form was changed from a liquid (20% of solids) to a dry meal.

The effects of dietary phosphorus level upon calcium and phosphorus utilization are shown in data presented in table 1. Pigs receiving 0.4 or 0.5% of dietary phosphorus excreted similar amounts of fecal and urinary phosphorus. Animals receiving the higher concentrations of dietary phosphorus excreted proportionately greater amounts of phosphorus, particularly in the urine, than animals receiving 0.5% of phosphorus. This resulted in similar phosphorus retention by pigs receiving dietary phosphorus levels of 0.5 to 0.8% which was significantly greater than that of pigs receiving 0.4% of phosphorus. Pigs receiving the lower levels of dietary phosphorus retained a higher percentage of the phosphorus intake than animals receiving 0.7 or 0.8% of phosphorus.

Fecal calcium excretion was significantly greater by pigs receiving 0.4% of phosphorus than by animals receiving the higher levels of dietary phosphorus. This appears to be an effect of the low level of dietary phosphorus per se, but it is also possible that this reduced apparent calcium
absorption may be due to dietary source of calcium since more of the calcium in the low phosphorus diet is being supplied in the less soluble carbonate form. The latter possibility does not, however, appear to be operative since no stepwise decrease in fecal calcium excretion occurs with other alterations of CaCO₃ and CaHPO₄·2H₂O as dietary phosphorus level is increased beyond 0.5%. Furthermore, calcium digestibility studies with rats (10) and with cattle (11) have shown no significant differences in calcium utilization when added to the diet in the carbonate or phosphate forms. Urinary calcium excretion was unaffected by dietary phosphorus level, contributing 5 to 10% of the total calcium excreted. This relationship between urinary and fecal calcium excretion has been shown to be quite consistent (1, 5, 6). Increased fecal calcium excretion by pigs receiving 0.4% of phosphorus resulted in a significantly reduced calcium retention.

Since average dietary calcium intakes were equated the percentage calcium retention of pigs receiving 0.4% phosphorus was also significantly less than that of pigs receiving higher levels of dietary phosphorus. The effects of dietary phosphorus level upon calcium and phosphorus utilization by the baby pig are best illustrated by the graphs in figures 3 and 4. These indicate

**TABLE 1**

| Calcium and phosphorus excretion and retention as affected by dietary phosphorus level |
|-----------------------------------------------|-----------------------------------------------|
| Dietary phosphorus level, % | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 |
| No. of collections | 4 | 4 | 4 | 4 | 4 |
| Daily food intake, g | 700 | 700 | 700 | 700 | 700 |
| P balance | | | | | |
| Daily P intake, g | 2.8 | 3.5 | 4.2 | 4.9 | 5.6 |
| Daily fecal P, g | 0.3±0.03 | 0.3±0.03 | 0.5±0.04 | 0.8±0.03 | 0.8±0.14 |
| Daily urinary P, g | 0.1±0.07 | 0.1±0.03 | 0.5±0.03 | 1.0±0.15 | 1.5±0.13 |
| Daily P retention, % | 84±2.5 | 88±2.3 | 75±2.8 | 63±1.5 | 59±5.6 |
| Ca balance | | | | | |
| Daily Ca intake, g | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 |
| Daily fecal Ca, g | 2.0±0.2 | 1.1±0.1 | 1.2±0.1 | 1.3±0.1 | 1.2±0.2 |
| Daily urinary Ca, g | 0.1±0.08 | 0.1±0.02 | 0.1±0.01 | 0.1±0.01 | 0.1±0.02 |
| Daily Ca retention, g | 3.4±0.3 | 4.4±0.5 | 4.3±0.6 | 4.2±0.4 | 4.3±0.6 |
| Ca retention, % | 60±2.9 | 78±3.3 | 78±4.3 | 75±0.8 | 77±5.4 |

1 Coefficient of variation (standard deviation + mean) of all intake means is 0.14.
2 **Significantly different from 0.4% P mean value (P<0.05); ** P < 0.01.
3 ^Significantly different from other values (P<0.05); b P<0.01.
that the dietary phosphorus level for optimal utilization of calcium and phosphorus is about 0.5%.

LITERATURE CITED