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Calcium and Phosphorus Balance in Growing Kadon Pigs Fed Diets Containing Either Broken Rice or Cassava Chips

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Abstract: In the present experiment, the effect of consumption of either Broken Rice (BR) or Cassava Chips (CC) on calcium and phosphorus balance was studied in growing Kadon pigs. Sixteen male pigs with initial body weight of 10.4 + 1.8 kg were used in a completely randomized design. The experimental diets contained similar concentrations of calcium and phosphorus, but the intakes were somewhat higher in pigs fed the CC diet. Apparent calcium and phosphorus absorption, when expressed as a percentage of intake, was significantly lower in the pigs fed the CC diet. In the pigs fed the CC diet instead of the BR diet, fecal calcium and phosphorus excretion were significantly increased. These data indicate that when formulating pig diets containing either BR or CC as carbohydrate source the levels of calcium and phosphorus may be adjusted to take into account the different efficiencies of absorption.

Key words: Kadon pigs, broken rice, cassava chips, calcium balance, phosphorus balance

INTRODUCTION

Studies with rats (Heijnen *et al*., 1993; Schulz *et al*., 1993) and dogs (Beynen *et al*., 2001, 2002) have shown that the carbohydrate source of the diet can influence the absorption of minerals such as calcium, magnesium and phosphorus. The general idea is that less digestible carbohydrates stimulate mineral absorption. Less digestible carbohydrates will be fermented in the small intestine, leading to a lowering of the pH and an increase in the solubility of minerals (Heijnen *et al*., 1993). Soluble, rather than insoluble minerals are available for absorption (Brink *et al*., 1992), so that an increase in mineral solubility is associated with an increased absorption efficiency. For pigs it also has been reported that poorly digestible, but fermentable carbohydrates in the diet stimulate mineral absorption (Heijnen and Beynen, 1998). In the course of our studies (Vasupen *et al*., 2007a, b) with growing Kadon pigs we found that the carbohydrates in Broken Rice (BR) have a higher digestibility than those in Cassava Chips (CC). In the light of the above mentioned, it would be hypothesized that pigs fed a diet with BR would show a lower apparent absorption than those fed a diet with CC.

MATERIALS AND METHODS

Animals and experimental design: The pigs and diets had been used in a study described earlier (Vasupen *et al*., 2007b). The experiment involved 16 male growing Kadon pigs with an average body weight of 10.4±1.8 kg. The experimental diets were given to 8 pigs each. The pigs were individually penned in metabolic cages and had free access to water from nipple drinkers.

The pigs were subjected to a completely randomized, parallel design. The experimental period lasted 56 days. During the last 14 days feces and urine were collected quantitatively. During the first 9 days feed intake was measured followed by 5 days for sample collection.

Diets and feeding: The dietary carbohydrate sources were Broken Rice (BR) and Cassava Chips (CC)) that were obtained at a local market. The ingredient composition of the diets is shown in Table 1. The diets containing either BR or CC were formulated so that they were similar in crude protein content by adding soybean meal. Pigs were fed *ad libitum* twice daily at 07.00 am and 16.30 pm, with the daily allowance being equally divided between the 2 meals.

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Table 1: Composition of the experimental diets for native growing pigs

Ingredient	BR	CC
Broken rice	68.0	0.0
Cassava chip	0.0	58.0
Soybean meal	30.0	40.0
Salt	0.1	0.1
Di-calcium phosphate	0.5	0.5
L-lysine	0.3	0.2
DL-methionine	0.1	0.2
Premix*	1.0	1.0
Total	100.0	100.0

*1 kg of vitamin and mineral premix contained: vitamin A 650 mg (325,000 IU); vitamin D_3 750 mg (75,000 IU); vitamin E 150 mg (75 IU); vitamin B_{12} 1 mg; vitamin K_3 80 mg; riboflavin 300 mg; niacinamide 1,200 mg; pantothenic acid 540 mg; choline chloride 6,000 mg; Fe 4,700 mg; Zn 6,500 mg; Mn 4,500 mg; Co 20 mg; Cu 1,400 mg ; I 45 mg and carrier material 973.164 g

Measurements: For the determination of total tract digestibility of calcium and phosphorus, fecal samples were quantitatively collected in plastic bags attached to the pigs. The bags were changed at least twice daily and stored frozen (-20°C) pending analysis. Urine was collected in containers via the funnels underneath the cages. Urine was removed twice each day and stored at -20°C until the time of analysis. During collection and storage, 10 mL of 25% H_2SO_4 was added to each container every day. Diets and faeces were then dried at 60°C in a forced-air oven for 96 h and ground to pass a 1 mm screen. Diet samples were analyzed for proximate composition (AOAC, 1990). Urine and faeces were determined for calcium and phosphorus.

Statistical analysis: The effects of dietary carbohydrate source were evaluated for statistical significance by the Student's t-test (SPSS, 1998). All results are expressed as means±SD. The level of statistical significance was preset at $p<0.05$.

RESULTS AND DISCUSSION

Table 2 shows the analyzed composition of the experimental diets and confirms that the protein content of the BR and CC diet was similar. The calcium and phosphorus content did not differ much between the two diets. However, the CC diet contained more ash than did the BR diet.

The source of dietary carbohydrate did not have significant effects on growth performance (Table 3). However, the BR diet tended to raise body-weight gain, lower Dry Matter (DM) intake and have a favorable effect on the Feed Conversion Ratio (FCR). It is likely that the increased digestibility of macronutrients as seen on the BR diet (Vasupen *et al*., 2007a) had caused the tendency towards a lower DM intake because the requirement of metabolic energy would be met with less feed.

Table 2: Analyzed composition of the experimental diets

Item	BR	CC
Dry matter (%)	87.70	87.90
Crude protein, % of DM	17.40	17.80
Crude fat, % of DM	2.60	1.40
Crude fiber, % of DM	2.40	4.40
Ash, % of DM	4.70	6.70
Nitrogen-free extract, % of DM	71.50	69.10
Nitrogen, % of DM	3.01	2.94
Calcium, % of DM	0.51	0.56
Phosphorus, % of DM	0.42	0.44

Table 3: Effects of carbohydrate source on growth performance in growing Kadon pigs

Item	BR	CC	p-value
Initial BW, kg	14.5±1.900	14.60±2.300	0.972
Final BW, kg	32.6±3.500	30.40±3.100	0.206
Growth, kg	18.1±3.500	15.80±1.800	0.141
ADG, g d^{-1}	326.4±119.0	287.10±75.40	0.129
DMI, g d^{-1}	807.4±186.9	845.90±197.9	0.438
FCR	2.81±1.20	3.13±1.000	0.277

[a,b]Means in the same rows with different superscripts differ significantly ($p<0.05$)

The main purpose of this study was to examine the influence of the feeding of BR versus CC diets on the apparent absorption of calcium and phosphorus. Table 4 shows that the pigs fed the BR diet had somewhat lower intake of both calcium and phosphorus. The Kadon pigs fed the BR diet instead of the CC diet showed a significantly increased apparent absorption when expressed as a percentage of intake (Table 4). In keeping with the effect on the efficiency of absorption, the BR diet produced a significant decrease in the fecal excretion of both calcium and phosphorus. Urinary excretion of the 2 minerals was not affected by the carbohydrate source of the diet. The absolute amounts of calcium and phosphorus absorbed were similar for the BR and CC diet, which is explained by the combination of lower group mean intake and the higher efficiency of absorption on the BR diet.

The outcome in that the BR diet versus the CC diet stimulated the absorption efficiency of calcium and phosphorus is contrary to our hypothesis. It was expected that the higher digestibility of the carbohydrates in BR would be associated with a lower absorption efficiency of calcium and phosphorus. However, the observed (Vasupen *et al*., 2007a, b) difference in carbohydrate digestibility refers to faecal digestibility so that the location and extent of fermentation remains unknown. The hypothesis was formulated under the assumption that the less digestibile carbohydrates in CC would lead to extra fermentation and a lowering of the pH in the small intestinal contents. There is no experimental evidence for this assumption.

As mentioned above, the ash content of the BR diet was much lower than that of the CC diet. The lower ash intake on the BR diet was associated with a lower

Table 4: Intake, excretion and absorption (g d^{-1}) of nitrogen, calcium and phosphorus

Diets	BR	CC	p-value
Calcium			
Intake (g d^{-1})	4.28±0.91[a]	4.88±1.07[b]	0.020
Faeces (g d^{-1})	1.32±0.39[a]	2.03±0.71[b]	0.000
Absorbed (% of intake)	68.75±8.16[b]	58.90±9.99[a]	0.000
Absorbed (g d^{-1})	2.95±0.75	2.85±0.70	0.597
Urine (g d^{-1})	0.06±0.04	0.08±0.04	0.054
Phosphorus			
Intake (g d^{-1})	3.21±0.79[a]	3.65±0.85[b]	0.039
Feces (g d^{-1})	1.13±0.47[a]	1.53±0.57[b]	0.005
Absorbed (% of intake)	65.46±8.69[b]	58.78±10.00[a]	0.007
Absorbed (g d^{-1})	2.07±0.49	2.12±0.51	0.701
Urine (g d^{-1})	0.11±0.10	0.09±0.06	0.187

[a,b]Means in the same rows with different superscripts differ significantly ($p<0.05$)

digestibility of ash (Vasupen *et al*., 2007a). Possibly, the CC contained a high amount of insoluble ash. Perhaps the insoluble ash had formed complexes with calcium and phosphorus in the intestinal lumen (Brink *et al*., 1992), leading to diminished absorption of the 2 minerals on the CC diet. The inhibitory effect of the insoluble ash may have overruled the stimulatory effect, if any, of the carbohydrate source in the CC. As a consequence, the efficiency of mineral absorption was found to be greater instead of lower on the BR diet. The CC diet contained more soybean meal than the BR diet and thus may contained more phytate than the BR diet. Phytate may form insoluble complexes with calcium, whereas the phosphorus in phytate is poorly available. It is not unlikely that the higher level of phytate in the CC diet had contributed to a lowering of calcium and phosphorus absorption.

CONCLUSION

The apparent calcium and phosphorus absorption, when expressed as a percentage of intake, was significantly lower in the pigs fed the CC diet. In the pigs fed the CC diet instead of the BR diet, faecal calcium and phosphorus excretion were significantly increased. These data indicate that when formulating pig diets containing either BR or CC as carbohydrate source, the levels of calcium and phosphorus may be adjusted to take into account the different efficiencies of absorption.

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