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The Effect of True Dietary Calcium (Ca) to True Dietary Phosphorus (P) Ratio on Urine Volume in Grower Pigs

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Abstract. Water is one of the known essential nutrients required by pigs to optimize their production potentials. However, excessive intake of water by the pig leads to high volume of urine excretions resulting in difficulty in manure management. Inappropriate Ca to P ratio in pig diets is majorly responsible for high volumes of urine excretions. Therefore, the effects of true digestible Ca to true digestible P ratios on urine excretions were investigated. 36 Yorkshire barrows of 24.2 ± 1.9 kg body weight (BW) were used in the study in a randomized complete block design of 6 pigs per block. 6 diets with different ratios of Ca to P were formulated as :0.76:1, 0.98:1, 1.17:1, 1.39:1, 1.60:1 and 1.80:1 for diets 1, 2, 3, 4, 5 and 6, respectively. Animals were fed for 15d consisting of 10d adaptation to their diets and 5d of urine collection. Orthogonal linear and quadratic contrasts were used to separate means and significance level was set at $P \leq 0.05$. There were no significant ($P > 0.05$) differences in the volume of urine for animals on all dietary treatments. Nevertheless, pigs on diet 2 had numerically the least or smallest volume of urine excretions. It was thus concluded that narrower ratio of Ca to P should be employed in reducing urine volumes to ease manure management in the pig farm.

Key words: Ca to P ratio, Urine volume, Manure management and the Pig

Introduction

Water is one of the essential nutrients required by pigs to optimize its production as water is required by pigs for various physiological functions (NRC, 2012). This may not be unconnected with some important processes that water is involved with in the life of the pig, such as growth. However, it is important to note that in the pig under normal conditions the body water content is usually maintained within relatively narrow variation, as variation in the rate of water consumption is always matched with appropriate changes in the output of urine (NRC, 2012). To this point therefore, the three major factors that influence water intake are metabolic regulation of the effective circulating volume of fluid in the vascular system, changes in plasma osmolarity as well as changes in the acid-base balance within and between particular compartments (Mroz *et al.*, 1995). During production processes, the pig body water pool usually remains constant throughout the various physiological growth and development phases of the pig (Thacker, 2001).

At present, it has been recognized that one of the primary factors that influences frequent water consumption is the type or nature of the feed the pig is consuming particularly as it relates to the ratio of dietary Ca to P in the diet being consumed (Mroz *et al.*, 1995; NRC, 2012). Previous workers, including those of Pettey *et al*. (2006) had alluded to the fact that dietary ratio of Ca to P affects the rate of water consumption by the pig. However, to date from literature search there is no study that had investigated the effect of true dietary ratio of Ca to P on urine excretion in the pig.

Therefore, although water is an important nutrient required in adequate amount just as in other nutrients, it is very important that care be taken in its management as to avoid excessive water intake as to reduce the degree of pig urination, especially the one caused by inappropriate dietary ratio of Ca to P. This observation comes to the fore because inappropriate dietary Ca to P ratio causes mineral toxicity resulting in excess water intake as a means of physiological response for pigs to detoxify themselves (Mroz *et al.*, 1995; NRC, 2012). Excessive water intake leads to difficulties in the management of slurries, especially at the commercial setting.

Management-wise, the disposal of slurries with high urine contents are very difficult and time-consuming resulting in delay in the time it takes for re-stocking in the commercial setting thereby negatively affecting profit margins (Pettey *et al.*, 2006). Therefore, the objectives of this study are to investigate the effect of dietary ratios of Ca to P on urine volume excretion in the growing pig.

Materials and Methods

Animals and Management

36 Yorkshire barrows of 24.2 ± 1.9 kg body weight (BW) used in this study were acquired from Arkell Swine Research Station, University of Guelph. Pigs on arrival at the animal wing of the University of Guelph were randomly assigned to their metabolic crates (0.8 x 2.0 m) with tender-foot™ plastic floors housed in the experimental room that is environmentally and mechanically ventilated to provide an ambient temperature of 21 ± 2^0C. All the pigs had free access to water from automatic water nipples. Animals were fed for 15d as 10d of adaptation to their diets and 5d of urine collection. The day prior to urine collection the crates were thoroughly cleaned to ensure that urine was not contaminated with fecal materials. All experimental procedures were reviewed and approved by the University of Guelph Animal Care Committee and pigs were cared for according to the guidelines of the Canadian Council on Animal Care (CCAC, 1993).

Experimental Diets

6 corn and soybean meal – based diets to meet or exceed the NRC (2012) recommended levels of nutrient requirements for 20 to 50 kg BW pigs were formulated to be isocaloric, isonitrogenous, isofibrous but differed in their dietary Ca contents resulting in different Ca to P ratio diets (Table 1). This was achieved by manipulating Ca content by gradient increases in the level of limestone at the expense of cornstarch. Calculated levels of Ca and P in the diets were confirmed by their analyzed values (Table 2).

Table 1. Diet formulation for optimal Ca to P ratio in growing pigs (20 – 50kg body weight)

Ingredients (kg)	**Diet 1**	**Diet 2**	**Diet 3**	**Diet 4**	**Diet 5**	**Diet 6**
Soybean meal	27.07	27.07	27.07	27.07	27.07	27.07
Corn	66.00	66.00	66.00	66.00	66.00	66.00
Cornstarch	3.87	3.29	2.71	2.13	1.55	0.97
L-Lys-HCL (79% L-Lys)	0.17	0.17	0.17	0.17	0.17	0.17
L-threonine (100%)	0.05	0.05	0.05	0.05	0.05	0.05
Animal fat	0.05	0.80	1.10	1.40	1.70	2.00
Iodized salt	0.40	0.40	0.40	0.40	0.40	0.40
Limestone (38.5%)[1]	0.28	0.56	0.84	1.12	1.40	1.68
Dicalcium phosphate	0.86	0.86	0.86	0.86	0.86	0.86
Vit-Mineral Premix[2]	0.50	0.50	0.50	0.50	0.50	0.50
Antibiotic mixture	0.00	0.00	0.00	0.00	0.00	0.00
Titanium oxide	0.30	0.30	0.30	0.30	0.30	0.30
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Calculated nutritive values (DM basis)						
DE (MJ/Kg)	16.52	16.54	16.55	16.56	16.57	16.60
CP (%)	19.69	19.69	19.69	19.69	19.69	19.69
Total Ca (%)	0.45	0.57	0.70	0.83	0.94	1.07

Total P (%)	0.59	0.59	0.59	0.59	0.59	0.59
Total Ca to total P ratio	0.78	0.98	1.19	1.40	1.61	1.81
NDF (%)	11.29	11.29	11.29	11.29	11.29	11.29
ADF (%)	4.98	4.98	4.98	4.98	4.98	4.98

[1]Commercial feed grade limestone. [2]Vit-mineral premix contained per kg of premix: vit. A, 2,000,000IU; vit. D_3, 200,000IU; vit. E, 8,000IU; vit. K, 500mg; pantothenic acid, 3,000mg; riboflavin, 1,000mg; folic acid, 400mg; niacin, 5,000mg; thiamine, 300mg; pyridoxine, 300mg; vit. B_{12}, 5,000mcg; biotin, 40,000mcg; Se, 60mg; choline, 100,000mg; I, 100mg; Cu, 3,000mg; Fe, 20,000; Mn, 4,000mg; Zn, 21,000mg.

Table 2. Calculated and analyzed concentrations of Ca and P in experimental diets (DM basis)

Item	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Ca concentration (%)						
Calculated values	0.45	0.57	0.70	0.83	0.94	1.07
Analyzed values	0.44	0.58	0.69	0.83	0.94	1.06
P concentration (%)						
Calculated values	0.59	0.59	0.59	0.59	0.59	0.59
Analyzed values	0.59	0.59	0.59	0.60	0.59	0.59
Calculated Ca to P ratio	0.78: 1	0.98: 1	1.19: 1	1.40: 1	1.61: 1	1.81: 1
Analyzed Ca to P ratio	0.76: 1	0.98: 1	1.17: 1	1.39: 1	1.60: 1	1.80: 1

Experimental Design

Experiment was designed and carried out as a randomized complete block design with 6 pigs per block involving a total of 6 blocks. Urine samples were collected via funnel-shaped metal trays secured to the base of the metabolic crate and covered with a netted screen mesh to prevent urine contamination with fecal materials. The containers contained 6N hydrochloric (HCL) acid solution made with milli-Q water (Millipore Corporation) to access Ca and P levels in the urine to evaluate true Ca and P retentions in a related investigation from this study. The total volume of urine collected each day/pig/block was recorded and stored at -23^{0}C. The experimental data were analyzed as a randomized complete block design. Data were subjected to analysis of variance (ANOVA) using mixed model procedure of SAS. Pigs served as the experimental unit. Orthogonal linear and quadratic contrasts were used to separate means and significance level was set at $P \leq 0.05$.

Results

The results of the 6 gradient levels of dietary ratio of Ca to P ratios on urinary excretions (litres) in the growing pig (20 to 50 kg) fed corn/SBM-based diets are shown in Table 3.

Table 3. Effects of 6 gradient levels of dietary Ca to P ratios on urinary excretions in growing pig (20 – 50 kg) fed corn/SBM-based diets (n = 6)

Item	0.35	0.49	0.57	0.67	0.60	0.61	SEM	***P - value***	
								Linear	Quadratic
Volume of urinary excretions (L)	15.37	10.44	14.37	11.43	13.77	13.87	0.22	0.89	0.24

Changes in the true digestible Ca to true digestible P had no significant (*P > 0.05*) effects on total volume of urine excreted. Nevertheless, pigs on diets 1, 3, 4, 5 and 6 had numerically higher urine volume excretions compared with pigs on diet 2 that had a narrower ratio of Ca to P of 0.98: 1.

Discussion

It is very important to note that under normal conditions, the water content of the pig's body is maintained within a relatively narrow limits as variation in the rate of water consumption is matched by appropriate changes in the output of urine (Kober, 1993). According to these authors, Veenhuizen (1993), Mroz *et al.* (1995) and Patience *et al.* (1995) there are three primary factors influencing spontaneous drinking of water and its equilibrium in the body, namely: metabolic regulation of the effective circulating volume of fluid in the vascular system, changes in plasma osmolality and changes in the acid-base equilibrium within and between particular compartments.

However, at present information on the underlying physiological mechanisms regulating water consumption is limited coupled with the difficulties in establishing the impact of some extrinsic factors, such as ambient temperature, humidity, diet quality and quantity, frequency of water provision, maintenance conditions or stress. In this current study however, pigs on diet 2 had the least total volume of urinary excretion. A high concentration of water in the manure usually increases costs of storage and disposal (Patience *et al.*, 1995).

Water in manure originates mainly from excreted urine that is known to be closely related to water intake (NRC, 2005). Therefore, it can be postulated that the inappropriate true dietary digestible Ca to true dietary P ratio in diet 1 coupled with higher concentrations of Ca in diets 3, 4, 5 and 6 might in part have been responsible for higher amounts of water intake by those pigs based on the numerically higher volumes of urine excreted by the pigs on those diets compared with pigs on diet 2. Furthermore, the higher water intake by the pigs observed in this study might be a physiological response or adaptation to consume more water as a physiological means to detoxify themselves in order to be able to tolerate inappropriate electrolyte balance (Flipot & Ouellet, 1988; Patience *et al.*, 1995). To this point therefore, this may be an additional economic benefit in using true digestible Ca to true digestible P ratio in the formulation of diets for pigs as to reduce the level of urine in the pig manure leading to reduced costs of manure management, storage and disposal (Aarnink & Verstegen, 2007).

Conclusion

Narrow true digestible Ca to true digestible P ratio such as 0.98 to 1 should be employed in diet formulations for grower pigs as to reduce the level of water intake and consequently reduce amount of urination as to ease manure handling.

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