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Feed intake, growth, digestibility of dry matter and nitrogen in young pigs as affected by dietary cation–anion difference and supplementation of xylanase[1]

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Summary

An experiment was conducted to test the effect of dietary cation–anion difference (CAD, $Na^+ + K^+ - Cl^-$, mEq/kg diet) and xylanase addition on feed consumption, digestibility of nutrients, plasma electrolyte balance and growth performance in young pigs. A 2×3 factorial arrangement with three dietary CAD levels (−100, 200, and 500 mEq/kg) and two levels of xylanase supplementation (0 and 0.1% xylanase derived from *Trichoderma longibrachiatum*) was used. Thirty-six individually housed, castrated pigs (5 weeks old) with an initial body weight of 9.34 ± 0.28 kg (mean ± SEM) were randomly assigned to the six treatments. Diets were provided to pigs as cold pellets. Pigs had *ad libitum* access to feed and water. Venous plasma Cl^- concentration was higher ($p < 0.0001$) in dietary CAD of − 100 mEq/kg group compared with the other two CAD groups. Dietary CAD did not affect Na^+ and K^+ concentrations in the venous plasma. Growth rates were higher ($p < 0.05$) in pigs receiving dietary CAD of 200 mEq/kg (657 g/pig.day) and dietary CAD of 500 mEq/kg (603 g/pig.day) than in pigs receiving dietary CAD of −100 mEq/kg (484 g/pig.day). Faecal dry matter and nitrogen decreased with increasing dietary CAD. Faecal apparent digestibility of dry matter and nitrogen was higher ($p < 0.05$) in the dietary CAD of 500 mEq/kg compared to the two lower level CAD groups. Supplementation of xylanase did not affect the performance of pigs. Xylanase addition in the diet significantly increased apparent faecal digestibility of dry matter and tended to increase apparent digestibility of nitrogen. No interaction between dietary CAD and xylanase was found. In conclusion, dietary CAD influenced the performance and digestibility of nutrients of pigs. Xylanase supplementation improved digestibility of dry matter.

Introduction

In pigs, feed intake and growth are related to dietary cation-anion difference (CAD, $Na^+ + K^+ - Cl^-$, mEq/kg diet) (PATIENCE et al. 1987; HAYDON et al. 1990). However, different optimal dietary CAD was observed in different studies (AUSTIC et al. 1983; PATIENCE et al. 1987; PARK et al. 1994; PATIENCE and CHAPLIN 1997). HAYDON et al. (1990) observed a linear increase in feed intake and growth of pigs with dietary CAD ranging from 25 to 400 mEq/kg. While PATIENCE et al. (1987) observed that feed intake and growth were maximal for dietary CAD between 0 and 340 mEq/kg. AUSTIC et al. (1983)

suggested that dietary CAD could influence lysine utilization in pigs. The inconsistent optimal dietary CAD levels may be caused by different diet compositions used in the mentioned studies.

Wheat and barley-based pig diets contain a high proportion of dietary fibre, pigs are not capable of digesting dietary fibre by means of their own digestive enzymes (TROWELL et al. as cited by INBORR 1994). Adding fibre-degrading enzymes to diets that contained high concentration of dietary fibre has improved pig performance (NEWMEN et al. 1983) and nutrient digestibility (GRAHAM et al. 1989; BEDFORD et al. 1992; INBORR et al. 1993). Mineral digestibility may also be influenced by supplementation of fibre-degrading enzymes (VAN DER KLIS 1993). It was reported that addition of endoxylanase enhanced the apparent absorption of calcium, magnesium, sodium and potassium from the jejunal lumen in broilers fed a wheat-based diet (VAN DER KLIS et al. 1995). Therefore inclusion of feed enzyme may interact with dietary CAD.

The objectives of this study are (1) to determine an optimal dietary cation–anion difference (CAD) on wheat/barley-based diet in young pigs; (2) to test the effect of exogenous feed enzyme (xylanase) on digestibility of nutrients; (3) to test if there is an interaction between feed enzymes addition and dietary CAD.

Materials and methods

Pigs and experimental design

A 2 × 3 factorial arrangement with three levels of dietary CAD and two levels of enzyme supplementation was used in this experiment. The experiment consisted of a 1-week adaptation period followed by a 5-week test period. A total of 36 5-week-old castrated pigs (F1 of female [Dutch Landrace × Finnish Landrace] × male [Cofok breed × Great York]) and with initial body weight of 9.34 ± 0.28 kg (mean ± SEM) were randomly assigned to the six treatment groups. The pigs were individually housed in pens (1.08 × 2.75 m, one-third slatted concrete floor, feeding trough made of baked clay). Pigs were allowed to adapt to the new environment for 1 week with a commercial diet before the experiment. Temperature of the room was maintained between 22 (night) and 29° C (day) throughout the experimental period. The Animal Welfare Committee of Wageningen University approved the protocol of this experiment.

Diets and feeding

Six diets were formulated in a 3 × 2 factorial arrangement, included three dietary CAD levels (−100, 200, and 500 mEq/kg), and two enzyme levels (0 or 0.1% xylanase addition, the latter containing a guaranteed minimum activity of 4000 units xylanase per kg feed, derived from *Trichoderma longibrachiatum*, supplied by Finnfeeds Ltd). The basal diet consisted of wheat, barley, rye, soybean isolate and premix (Table 1), with a calculated CAD level of 172 mEq/kg. The designed dietary CAD levels were achieved by addition of $CaCl_2 \cdot 2H_2O$ or $NaHCO_3$, respectively. $CaCl_2 \cdot 2H_2O$ was used to lower dietary CAD levels because it was observed that addition of $CaCl_2 \cdot 2H_2O$ reduced feed intake in pigs (YEN et al. 1981). To avoid biased results due to variation in calcium concentrations, calcium levels were maintained constant in each diet by addition of $CaCO_3$. Diamol (diatomaceous shell powder, Biakon N.V., Grobbendonk, Belgium) was added in the diet to keep ash content constant. Enzyme was added by replacement of diamol. All test diets were formulated to meet or exceed the nutrient requirements (NRC 1988) for young pigs (Table 2). The feed was provided *ad libitum*, as cold pellet, for 23 h daily. In the middle and the end of the experiment before blood sampling, pigs were not provided feed for one night and were then fed to satiation in the next morning. Water was freely available throughout the experimental period.

Table 1. **Basal diet composition**

Ingredients	%
Barley	41.6
Wheat	20
Rye	20
Soybean isolate	13
Tallow	2
Limestone	0.8
Monocalcium phosphate	0.8
Salt (KCl)	0.3
L-lysine HCl	0.3
DL-methionine	0.1
Premix[a]	1.0
L-threonine	0.1

[a] The vitamin and mineral premix supplied per kg of the basal diet with 9000 IU of vitamin A 1800 IU of vitamin D_3, 40 mg of vitamin E, 5 mg of riboflavin, 30 mg of niacin, 12 mg of d-pantothenic acid, 350 mg of choline chloride, 40 μg of vitamin B_{12}, 3 mg of vitamin K, 50 mg of vitamin C, 1 mg of folic acid, 0.1 mg of biotin, 0.52 mg of Co as $CoSO_4 \cdot 7H_2O$, 0.06 mg of Se as $Na_2SeO_3 \cdot 5H_2O$, 0.12 mg of I as KI, 80 mg of Fe as $FeSO_4 \cdot 7H_2O$, 170 mg of Cu as $CuSO_4 \cdot 5H_2O$, 44 mg of Mn as MnO_2, 73 mg of Zn as $ZnSO_4 \cdot H_2O$

Table 2. **The composition of test diets as fed**

Dietary CAD (mEq/kg)	−100		200		500	
Xylanase	0	0.1%	0	0.1%	0	0.1%
Ingredients (%)						
Basal diet	95		95		95	
$CaCl_2 \cdot 2H_2O$	1.93					
$NaHCO_3$			0.31		2.83	
$CaCO_3$			1.36		1.36	
Diamol[a]	3.07		3.33		0.81	
Analysed composition (%)						
Dry matter	88.7	89.4	89.5	89.8	89.3	89.3
Crude protein	19.6	19.8	19.9	20.0	19.9	19.9
Crude fibre	2.83	2.86	2.86	2.77	2.91	2.92
Ash	7.31	7.37	7.84	7.95	7.15	7.15
P	0.53	0.53	0.53	0.53	0.54	0.53
Ca	1.0	1.0	0.97	0.98	0.99	1.0
Na	0.19	0.17	0.30	0.31	1.07	1.07
K	0.60	0.57	0.52	0.53	0.54	0.55
Cl	1.1	1.2	0.28	0.31	0.33	0.31
Dietary CAD (mEq/kg)[b]	−84	−115	182	185	510	517
Acid binding capacity (mEq.kg $^{-1}$)[c]	499	509	800	817	1193	1168

[a] Diamol is diatomaceous shell powder (Biakon N.V., Grobbendonk, Belgium)
[b] Calculated as Na + K − Cl
[c] Quantity of 1.0N HCl required for the gastric digestion pH (3.0) of 1 kg feed

Sampling and measurements

Feed intake was recorded daily. Weight gain was measured weekly. Faecal apparent digestibility of nitrogen and dry matter (DM) was measured using acid insoluble ash (AIA) as an indicator (McCarthy et al. 1974; Wunsche et al. 1991). Diet samples were taken

every day during the experiment for feed composition analysis. Faecal samples (grab samples) were collected during experimental weeks 1, 3 and 5. In each of these weeks the faecal samples were taken on three successive days. These samples were stored in a freezer (−20° C) until the end of the experiment. Before analysis the samples from all 3 days per week 1, 3 and 5 were pooled, then subsamples were taken for DM and nitrogen analysis. The remaining samples were freeze-dried. Dry matter and AIA were measured from freeze-dried samples. The nitrogen content of feed and faeces was analysed by the Kjeldahl method (ISO 5983 1979). Dry matter content of feed and faeces, ash content of feed and AIA content of feed and faeces were measured according to ISO procedures [ISO 6496 (1983); ISO 5984 (1978) and ISO 5985 (1978), respectively]. Dietary Ca concentration was measured using atomic absorption spectrometry (ISO 6869 1997) and dietary P concentration was measured using spectrophotometry (ISO 6491 1995).

Blood samples were taken by puncture of the vena cava. At the start of the experiment (day 0), blood samples were taken from 12 randomly selected pigs (two from each treatment) for initial values. In the middle (day 16–18) and the end (day 34–36) of the experiment the blood samples were taken from all 36 pigs on three successive days with 12 piglets (two from each treatment) on each day. Before blood sampling the pigs were given *ad libitum* access to feed for 30 min at 08.00 h, after an overnight fast. The blood samples were taken 2.5 h after feeding, when an important part of the nutrients in the feed would have been absorbed in the small intestine. The blood samples were centrifuged at 1600*g* for 15 min to obtain the blood plasma fraction. The plasma samples were then stored at −20° C until analysed for Cl^-, $Na^+$and K^+ concentrations.

Plasma Cl^- concentration was measured using a chloride meter (PCLM digital chloride meter, Jenway Ltd, Dunmow, UK). Plasma Na^+ and K^+ were measured using a flame photometer (PFP 7 flame photometer, Jenway Ltd, Dunmow, UK). Chloride, Na and K in the diets were determined as described by FAUCHON et al. (1995) with some modifications. One gram feed sample was dissolved in 10 ml demineralized water, incubated at 37° C in an oven for 1 h and Cl^- concentration in the solution was measured using the same instrument as for plasma Cl^-. The diet sample was used instead of ash sample for measuring Cl^- in the feed because ash samples resulted in unexplained low values. For measuring Na^+ and K^+, 0.5 g ash samples were dissolved in 1 M HCl solution and the Na^+ and K^+ concentrations in the solution were measured using the same instrument as for plasma. Acid binding capacity of the feed was measured by the method of PROHASZKA and BARON (1980). Two grams of feed were incubated in 20 ml 0.1 M HCl solution at 37° C for 1 h. Afterwards the suspension was titrated with 0.1 M NaOH up to pH = 3.0. Acid binding capacity was calculated as the quantity of HCl required per kg diet for lowering the dietary pH = 3.0 (mEq/kg).

Data analysis

The average value of 5 weeks trials were calculated for weight gain, feed intake and feed conversion. Feed conversion (FC) was defined as kg feed consumed per kg weight gain. Digestibility was calculated according to the following equation:

$$\text{Di\%} = 100 - 100 \times [(\%\ \text{AIA in feed} \times \%\ \text{nutrient in faeces})/(\%\ \text{AIA in faeces} \times \%\ \text{nutrient in feed})]$$

Where Di% is the digestibility of nutrients in percentage and AIA is the acid insoluble ash. Mean plasma Na, K and Cl concentrations were calculated as the average of the values obtained in the middle and the end of the experiment. The measured values from weeks 1, 3 and 5 were averaged for faecal dry matter, nitrogen and their digestibility. For all measured parameters mean values were used for statistical analysis.

Statistical analysis

Data were analysed according to the General Linear Model procedure of SAS (SAS 1990). The effects of dietary CAD, enzyme and their interaction were tested by two-way ANOVA. LSM procedure was used to compare treatment means.

Results

Plasma minerals

Venous plasma Cl^- concentration was significantly lower ($p < 0.001$) in pigs fed – 100 mEq/kg CAD diet compared with pigs fed 200 and 500 mEq/kg CAD diets. Plasma Cl^- concentration and the growth performance (in $g/kg^{0.75}$/day) of the pigs were negatively correlated ($r = -0.71$) (Fig. 1). However, neither dietary CAD nor xylanase in the diet had an effect ($p > 0.10$) on venous plasma Na^+ and K^+ concentrations (Table 3).

Feed consumption, growth and feed utilization

Dietary CAD levels significantly affected the growth performance of pigs. At a dietary CAD level of – 100 mEq/kg, growth was lower ($p < 0.01$) than at other two dietary CAD

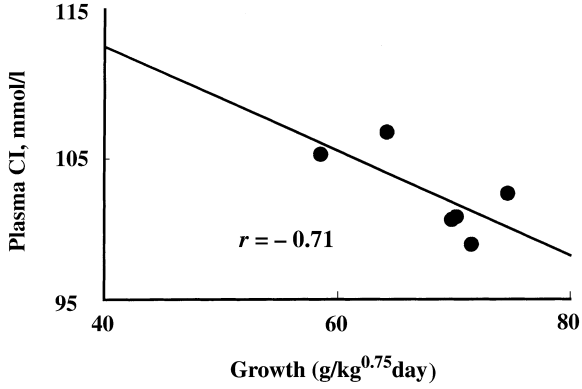

Fig. 1. Correlation between plasma Cl^- concentration (mmol/l) and the growth ($g/kg^{0.75}$/day) of pigs

Table 3. **Plasma Na, K and Cl concentrations[1,a]**

Dietary CAD (mEq/Kg)[b]	–100		200		500			p-values[c]	
Xylanase	0	0.1%	0	0.1%	0	0.1%	SEM	CAD	Enzyme
Plasma Cl[d]	105.0	106.5	102.3	100.7	98.8	100.5	1.24	0.0001	0.6
Plasma Na	146.6	143.3	143.2	141.4	140.2	146.2	4.45	0.7	0.9
Plasma K	5.82	5.94	5.80	6.02	6.10	6.24	0.297	0.6	0.5

[1] Values are the mean values (mmol/l) measured in the middle and the end of the experiment
[a] The start values for plasma Cl, Na and K were 101.5, 125.6 and 4.88 mmol/l, respectively
[b] CAD is defined as $Na^+ + K^+ - Cl^-$ (mEq/kg)
[c] No CAD and feed enzyme interaction was found ($p > 0.3$)
[d] CAD group of – 100 mEq/kg significantly differ from CAD groups of 200 and 500 mEq/kg ($p < 0.05$)

Table 4. **Feed intake, growth and feed conversion, average value of 5 weeks[a]**

Dietary CAD (mEq/kg)[b]	– 100		200		500			p-values[c]	
Xylanase	0	0.1%	0	0.1%	0	0.1%	SEM	CAD	Enzyme
Feed intake (g/pig day)	787	839	980	858	938	1006	62.8	0.08	0.8
Growth (g/pig day)[d]	484	532	657	593	603	651	34.1	0.002	0.5
Feed conversion	1.78	1.60	1.50	1.47	1.59	1.61	0.085	0.07	0.4

[a] Provisional data and results were given in the Proceeding of International Conference on Pig Production, 6–8 July 1998, Beijing, China
[b] CAD is defined as $Na^+ + K^+ - Cl^-$ (mEq/kg)
[c] No CAD and feed enzyme interaction was found ($p > 0.10$)
[d] CAD group of – 100 mEq/kg significantly differ from CAD groups of 200 and 500 mEq/kg ($p < 0.05$)

levels (Table 4). Dietary CAD tended to influence feed intake and feed conversion ($p < 0.10$). Supplementation of xylanase had no effect on feed intake, growth rate and feed conversion of pigs.

Faecal composition and digestibility

Faecal DM ($p < 0.001$) and faecal nitrogen ($p < 0.05$) content decreased with increasing of dietary CAD levels. Pigs fed dietary CAD of −100 mEq/kg showed higher faecal dry matter and nitrogen content compared to dietary CAD of 200 and 500 mEq/kg. Enzyme supplementation ($p < 0.052$) increased faecal DM content but did not influence faecal nitrogen content. There was no interaction between dietary CAD and feed enzyme (Table 5).

Dietary CAD of 500 mEq/kg resulted in significantly higher faecal apparent digestibility of DM and nitrogen than the other two dietary CAD levels (Table 5). Faecal apparent digestibility of DM increased ($p < 0.04$) and apparent digestibility of nitrogen tended to increase when xylanase was added to the diets ($p < 0.07$).

Table 5. **Faecal dry matter and nitrogen content and their apparent digestibility[1]**

Dietary CAD (mEq/kg)[a]	– 100		200		500			p-values[b]	
Xylanase	0	0.1%	0	0.1%	0	0.1%	SEM	CAD	Enzyme
Faecal composition (g/kg)									
Dry matter[c]	380	398	341	362	294	323	14.3	0.0001	0.052
Nitrogen[d]	12.3	13.1	11.5	12.0	11.9	11.4	0.45	0.05	0.5
Digestibility (%)									
Dry matter[e]	81.8	82.7	80.6	80.7	88.7	89.7	0.424	0.0001	0.036
Nitrogen[f]	83.2	83.7	81.4	81.9	87.6	89.6	0.865	0.0001	0.07

[1] Data are means of week 1, 3 and 5 of the experiment
[a] CAD is defined as $Na^+ + K^+ - Cl^-$ (mEq/kg)
[b] No CAD and feed enzyme interaction was found ($p > 0.10$)
[c] In order of significance: – 100 mEq/kg CAD > 200 mEq/kg CAD > 500 mEq/kg CAD ($p < 0.05$)
[d] – 100 mEq/kg CAD was significantly higher ($p < 0.05$) than 200 and 500 mEq/kg CAD
[e] In order of significance: 500 Eq/kg CAD > – 100 mEq/kg CAD > 200 mEq/kg CAD ($p < 0.05$)
[f] 500 mEq/kg CAD was significantly higher ($p < 0.05$) than – 100 and 200 Eq/kg CAD

Discussion

Plasma minerals

The high plasma Cl^- concentration in the low dietary CAD group as found in the present study agrees with the observations in the literature (PATIENCE and WOLYNETZ 1990; PATIENCE and CHAPLIN 1997). The high plasma Cl^- concentration may be associated with high Cl^- content in the −100 mEq/kg CAD diet. YEN et al. (1981) also found an increase in plasma Cl^- concentration in pigs fed a diet containing high Cl^- (4% of $CaCl_2 \cdot 2H_2O$). PATIENCE and CHAPLIN (1997) compared a diet with −20 mEq/kg CAD level to a diet with 104 mEq/kg CAD level on minerals balance. The two diets had similar chloride content. But the 104 mEq/kg CAD diet had additional Na^+ and K^+. They found that the Cl^- concentration in the serum was significantly lower in the −20 mEq/kg CAD group than the other dietary CAD group. This indicates that plasma Cl^- is influenced by dietary CAD component other than Cl^-. Furthermore the high Cl^- in the serum was associated with low HCO_3^- concentration in the serum or vice versa. Increasing dietary CAD can increase HCO_3^- concentration in the blood (PATIENCE et al. 1987). KEMME-KROONSBERG (1993) suggested that when HCO_3^- is increased in the plasma, an equivalent amount of Cl^- has to be excreted in order to maintain electroneutrality in the extracellular fluid. This might explain why plasma Cl^- concentration decreased with an increase of dietary CAD or vice versa. In the present study, although Na^+ content in the diet increased with increasing dietary CAD, plasma Na^+ concentration was not changed. This is in agreement with PATIENCE and CHAPLIN (1997), who also found that Na^+ and K^+ concentrations in the serum were not influenced by dietary CAD in pigs. HAYDON et al. (1990) as well as PATIENCE and WOLYNETZ (1990), however, observed a linear increase in blood Na^+ concentration with increasing dietary CAD levels. In our previous study (unpublished data), we also found that blood Na^+ concentration was higher at 200 mEq/kg CAD level compared to −100 mEq/kg CAD level. In the present study, dietary K^+ was kept constant among treatment groups, this may explain the constant K^+ concentration in the plasma. Some other studies also support this result (HAYDON et al. 1990; PATIENCE and WOLYNETZ 1990).

Feed consumption, growth and feed conversion

Growth rate was depressed in pigs fed the −100 mEq/kg CAD diet. Increasing dietary CAD to 200 mEq/kg significantly improved the performance of pigs. A further increase of dietary CAD from 200 to 500 mEq/kg slightly decreased intake and weight gain in the group without enzyme addition. This suggested that an optimal dietary CAD could be between 200 and 500 mEq/kg.

In general, a negative dietary CAD results in poor performance. Increasing dietary CAD improves feed intake and growth in many animal species. In this study increasing dietary CAD from −100 to 200 mEq/kg resulted in an increase of 24% in feed intake and 36% in weight gain. PATIENCE et al. (1987) found that optimal dietary CAD for young pigs was around 175 mEq/kg. The results of the study of AUSTIC et al. (1983) suggested that dietary CAD ranging from 100 to 300 mEq/kg permitted optimal performance of pigs. On the other hand, PARK et al. (1994) found an optimal dietary CAD of 50–150 mEq/kg for weaning pigs.

Many studies showed that a diet with excess anion (Cl^-) resulted in high Cl^- content in the plasma, reduced blood pH, bicarbonate and base excess (YEN et al. 1981; PATIENCE et al. 1987; PATIENCE and CHAPLIN 1997). This may depress feed intake and growth. YEN et al. (1981) found that inclusion of 4% $CaCl_2 \cdot 2H_2O$ in pig feed resulted in metabolic acidosis and reduced feed intake and growth rate.

Dietary CAD did not significantly influence feed intake, this was associated with large within-group variations. However, the data showed a clear towards a low feed intake at

low dietary CAD level, especially for the groups not supplemented with xylanase. This positive effect of dietary CAD on feed intake has been observed in many other studies. PATIENCE et al. (1987) observed a linear and quadratic increase in feed intake with increasing dietary CAD from −85 to 341 mEq/kg in pigs. HAYDON et al. (1990) showed a linear increase in daily feed intake with increasing dietary CAD from 25 to 400 mEq/kg. In the present study, feed conversion tended to decrease with increasing dietary CAD levels. PATIENCE and WOLYNETZ (1990) reported a linear increase in feed efficiency with increasing dietary CAD from −176 to 248 mEq/kg. In contrast, PATIENCE et al. (1987) and HAYDON et al. (1990) found that dietary CAD affected feed intake and growth, but feed efficiency was not changed.

Overall, xylanase addition did not influence growth performance of pigs. Dietary CAD and xylanase did not interact with regard to performance. However, comparing performance responses at individual dietary CAD levels, xylanase addition numerically increased feed intake and growth at dietary CAD levels of −100 and 500 mEq/kg. But it numerically decreased feed intake and growth at a dietary CAD level of 200 mEq/kg.

Faecal composition and digestibility

A high dietary CAD resulted in low dry matter content in faeces. This may have been a consequence of high water intake in the high dietary CAD group. In a previous experiment we observed a higher water intake in dietary CAD of 200 mEq/kg group compared to the −200 mEq/kg CAD group (unpublished data). PATIENCE and CHAPLIN (1997) observed an increase in water intake and water to feed ratio in pigs fed a diet with CAD level of 104 mEq/kg compared to a diet with a CAD level of −20 mEq/kg. However, dietary CAD did not affect the water retention.

The digestibility of DM and nitrogen was higher in the pigs fed 500 mEq/kg CAD diet compared to the pigs fed the other two lower CAD diets. This was associated with low faecal DM and nitrogen content at a CAD of 500 mEq/kg. This is in contrast to the observations by HAYDON & WEST (1990), who found that dietary CAD levels did not affect faecal nitrogen, although it numerically decreased with increasing dietary CAD.

The inclusion of xylanase significantly increased faecal digestibility of DM and tended to improve faecal digestibility of nitrogen. This is in agreement with BEDFORD et al. (1992) and INBORR et al. (1993). Xylanase inclusion increased the faecal apparent digestibility of DM at dietary CAD levels of −100 and 500 mEq/kg compared to dietary CAD level of 200 mEq/kg. This may partly explain the numerical increased growth by addition of feed enzyme at these two dietary CAD levels. Addition of feed enzyme did not interact with dietary CAD. This may imply that enzyme did not influence minerals digestibility or the enzyme effect on nutrient digestibility was not strong enough to obtain this interaction.

In conclusion, this study showed that a dietary CAD level of −100 mEq/kg depressed growth of young pigs. Whereas dietary CAD between 200 and 500 mEq/kg improved the performance of young pigs. Therefore, when a pig feed is formulated, an optimal dietary cation–anion difference should be considered. Impaired feed intake and growth may be the result of suboptimal dietary CAD level. Enzyme addition improved digestibility of dry matter. However, no dietary CAD and feed enzyme interaction was found in this study.

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