HOW LOW CAN YOU GO?

OPTIMISING THE USE OF CALCIUM NITRATE (CAN) IN GESTATING SOW DIETS TO REDUCE PIGLET BIRTHWEIGHT VARIATION AND IMPROVE THEIR LIFETIME PERFORMANCE

6A-108

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By

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Executive Summary

As pig producers aim to increase the number of piglets born per litter, increases in litter size have resulted in an increase in the proportion of piglets born light (e.g. <1.1 kg) with reduced vitality at birth and therefore chance of survival to weaning.

Calcium nitrate (CAN), or $Ca(NO_3)_2$, supplemented to sows before farrowing may enhance blood flow to the placenta and improve foetal development of piglets. From our previous work (APRIL project 5A-104, *Low dose dietary strategies in late gestation to enhance born alive and piglet survival and performance*) it was observed that 0.1% CAN supplementation from d 90 of gestation until farrowing could reduce the proportion of piglets born <1.1 kg at birth, and improved pre-weaning survival rates. However, feeding a separate diet mid-gestation would require additional infrastructure on most farms, as sows at different stages of gestation are often housed in the same sheds with limited silo space and feed line configurations.

Therefore, the current project aimed to determine the optimal feeding time for CAN in sows before farrowing. We hypothesised that supplementation of CAN from entry to the farrowing house (approx. d 108 of gestation) until farrowing would significantly improve piglet birth weights and survival until weaning, as well as piglet growth performance to slaughter. Furthermore, we hypothesised that feeding CAN for this shorter period of time would give similar improvements in piglet birth weight and survival rates to that of CAN supplementation from approximately d 90 of gestation.

In this study, *n* = 320 sows (parities 1 to 8) were allocated over five time replicates to 1 of 4 treatments based on length of 0.1% CAN supplementation in the pre-farrowing diet: CON), no CAN supplemented; SHORT), CAN supplemented from entry to the farrowing house until farrowing; MED), CAN supplemented from approx. d 92 of gestation until farrowing; or, LONG), CAN supplemented throughout gestation. Several measures of gestation and lactation performance were taken from sows and their piglets, including individual birth weights and all mortalities and removals were recorded. A subgroup of male piglets (*n* = 100) in the first replicate were followed through intensive weaner and grower-finisher facilities to slaughter, where growth rates, feed intakes and carcass data were collected for these animals.

Contrary to our hypotheses, supplementation of CAN in sow diets did not significantly influence piglet birth weight, birth weight variation, survival to weaning, or lifetime growth performance. However, the current study was performed in a herd where there was adequate farrowing supervision which may have negated the positive impacts of feeding CAN on increased vitality in piglets at birth.

Therefore, we conclude that CAN supplementation to sows in gestation, either short-, medium- or long-term, does not significantly improve pre-weaning or lifetime performance of their piglets under the conditions of this study.

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1. Introduction

Calcium nitrate, or $Ca(NO_3)_2$ (hereby referred to as CAN), and other forms of nitrate have been used in human health to improve exercise performance (Jones, 2014; Omar et al., 2016), and nitrate supplementation is often used in ruminants to mitigate methane production and improve performance (Sun et al., 2017).

Two seminal studies have recently investigated the impacts of CAN supplementation in late gestation sow diets, and results may indicate that this additive could also be used to improve piglet vitality at birth (van den Bosch et al., 2019a,b). It is likely that the nitrate supplied to the sow through CAN supplementation can promote placental angiogenesis and vasculogenesis, thus enhancing blood flow to the placenta (Bird et al., 2003; Chang and Lubo, 2008) and improving the foetal development of piglets, particularly those suffering from uterine crowing and intrauterine growth restriction (IUGR). Improvements in vitality at birth may increase colostrum consumption by piglets, improving their immune competence and hence their chance of survival until weaning and beyond.

In a previous project conducted between Rivalea and APRIL (5A-104, *Low dose dietary strategies in late gestation to enhance born alive and piglet survival and performance*), it was found that feeding 0.1% CAN to sows from approximately d 90 of gestation until farrowing increased average piglet birth weight, largely by reducing the proportion of piglets born weighing <1.1 kg compared to sows fed a control diet or a diet with 0.5% arginine (ARG). This project also showed that CAN fed from d 90 of gestation until farrowing could improve survival rates of piglets to weaning.

However, depending on the feeding systems utilised on an individual farm basis, feeding sows from approx. d 90 of gestation until farrowing may not be practical. For example, sows in a dry sow facility are often at different stages of lactation and it is unlikely that a commercial system can feed more than one diet within a dry sow shed, which would require multiple silos and feed lines. Moreover, from entry into the farrowing house it is common for sows to receive a lactation (rather than gestation) diet, and hence on-farm storage may be limiting for an additional pre-farrowing ‘transition’ diet.

Given that feeding systems for gestating sows may be limiting for implementation of these late gestation diets (from d 90) on a commercial scale, it is critical to conduct further work into whether these additives can be fed just as a pre-farrowing transition diet (i.e., from entry to the farrowing house until the point of farrowing). This would allow a reduction in on-farm storage requirements and adaptation of existing feeding systems.

Therefore, the aim of the current study was to determine the optimal feeding time for 0.1% CAN to sows in gestation to maximise piglet performance from birth up until sale. It was hypothesised that CAN could be fed from entry to the farrowing house until farrowing and improve survival and growth performance of their piglets as effectively as feeding CAN from d 90 of gestation until farrowing, or throughout gestation.

2. Methodology

2.1 Animal welfare statement

This experiment was conducted at a commercial farm (Corowa NSW, Australia) between December 2022 and August 2023. All procedures described were undertaken with prior approval from the Rivalea Animal Ethics Committee (protocol number 22-014).

2.2 Gestation period

A total of 320 sows was selected at mating and their body weight (BWT) and P2 backfat measured via ultrasound. Sows were allocated to 1 of 4 dietary treatments based on parity (parities 1 to 8; average 2.5 ± 1.53), with a diet including 0.1% calcium nitrate (CAN; replacing wheat) being fed for 1 of 4 periods in gestation:

1. No CAN supplemented (CON);
2. Short term: 0.1% CAN supplemented from entry to the farrowing house (d 108 ± 0.8 of gestation) until farrowing (SHORT);
3. Medium term: 0.1% CAN supplemented from approximately d 90 (d 92 ± 0.7) of gestation until farrowing (MED); and,
4. Long term: 0.1% CAN supplemented from entry to the gestation facility (2 ± 0.5 d after mating) until farrowing (LONG).

Shortly after mating (2 ± 0.5 d), sows were moved to group housing in groups of 16 where they were floor-fed a restricted ration each day based on the number of sows in the pen; however, all sows in the pen were not guaranteed the same feed intake due to competition. Therefore, sows were housed with others allocated to the same dietary treatment in 5 pens per treatment. Sows on the LONG treatment started on the CAN gestation diet (13.2 MJ DE/kg, 13.4% CP, 3.4% fat, 0.53% available lysine) when moved into group pens, while the others were given a standard (control) gestation diet (13.2 MJ DE/kg, 13.4% CP, 3.4% fat, 0.53% available lysine). Due to re-penning of some sows in the fourth replicate as part of commercial procedures, the total number of sows in each treatment were *n* = 79, 81, 82 and 78, respectively. On d 92 of gestation, all sows had BWT and P2 backfat measured and sows on the MED treatment switched to the CAN gestation diet. It should be noted that the commercial farm where the experiment was conducted was converting to a batch farrowing system as the experiment was being carried out, which influenced some commercial procedures.

2.3 Lactation period

Sows entered the farrowing house at d 108 (± 0.6) of gestation, had their BWT and P2 backfat measured, and started on their lactation diets. Sows in the SHORT treatment (as well as those in the MED and LONG treatments) switched to the CAN lactation diet (14.8 MJ DE/kg, 15.9% CP, 7.8% fat, 0.83% available lysine) at this point, whereas CON sows were fed a standard (control) lactation diet (14.8 MJ DE/kg, 15.9% CP, 7.8% fat, 0.83% available lysine).

Before farrowing, sows were on a restrict-fed ration (approx. 2.4 kg/d) and then fed *ad libitum* throughout lactation. Average daily feed intake (ADFI) in lactation was recorded for each sow from farrowing until weaning. Unfortunately, some sows (*n* = 15) from the third replicate did not have lactation feed intake recorded due to a recording error. This data was treated as missing for these sows in the subsequent data analysis.

When farrowing could be observed during staffed hours (extended staffed hours were employed at the experimental farm during this study, e.g., from 0500 h to 2200 h during weekdays), farrowing sows were closely supervised. Piglets were picked up soon after birth, dried using drying powder, umbilical cords shortened close to the umbilicus, placed near the udder and encouraged to suckle, or placed under the heat lamp in the creep area.

Date of farrowing, number of piglets born alive (BA), stillborn, mummified and total piglets born (TB) were recorded for each litter. All piglets BA were weighed individually at birth and given an individual identification tag to follow through until weaning.

Due to several litters being fostered or piglets born dead or dying before fostering being taken away before they had a chance to be weighed (as a result of commercial farrowing house procedures), birth BWTs of piglets were considered in two ways:

a) Litter weight and average birth BWT of all liveborn piglets before fostering (*n* = 109);
b) Litter weight and average birth BWT of all piglets after fostering (*n* = 77).

The coefficient of variation (CV) for piglet BWT of piglets BA was calculated for each litter (before fostering). Piglets were fostered minimally as per commercial practices to match number of teats and standardise litters where possible. Where it could be done, fostering was done within sow dietary treatment.

A cohort of male piglets (*n* = 25 per treatment) were blood sampled within 24 h of birth. Blood samples were collected in Vacutainer tubes with clot activator (BD Vacutainer, Franklin Lakes NY, USA) via jugular venepuncture. Samples were then centrifuged at 5,500 x *g* for 15 min to separate serum and frozen at -20°C for later analysis.

All piglet mortalities before weaning were recorded for each litter. All pigs were individually weighed at approximately 21 d of age. All sows were weighed and P2 measured at the day of weaning (28 ± 3.34 d). All sow removals were recorded during lactation. Some sows were removed during lactation for management reasons (to become a foster mum or due to piglets not being weighed or moved into another non-experimental facility) and these removals were not included in the sow removal data analysis. It must be noted that a number of sows were culled after weaning for management reasons, and hence could not have subsequent data collected, as the farm was moving to a batch-farrowing system at the time.

Subsequent reproduction data for all weaned sows, including farrowing rate (FR), wean to remate interval (WRI) and BA and TB in the subsequent litter was collected from farm digital records.

2.4 Post-weaning period (4 to 9 weeks of age)

A cohort of male piglets (*n* = 100) were selected at weaning (33 ± 1.2 d) and entered the individually housed weaner facility (Weaner Discovery Centre) in individual pens, fitted with a single drinker nipple and feeder attached to the side wall of the pen, and an electric heat lamp hanging above each pen. Pigs that were initially blood sampled at 24 h after birth were included in this cohort where possible. All pigs were individually weighed at entry to this facility and weekly until 9 weeks of age, where they were then moved into the grower-finisher facility (see section 2.5). A number of pigs in the shed were observed to have scours and were medicated with Lincomycin, both individually injected and pulsed through the water lines for 3 d in the second week after weaning (water medication given to all pigs). A small number of pigs were treated for meningitis with Penicillin and Meloxicam.

All pigs were fed common commercial early (0 to 14 d) and late weaner diets (15 to 35 d) *ad libitum* during this period, with any mortalities, removals and individual medications recorded. Feed reconciliation was carried out weekly to determine ADFI for each pig.

2.5 Grower-finisher period (9 weeks of age to sale)

All pigs in the weaner cohort were moved to the individually housed grower-finisher facility (Grower Discovery Centre) at 68 (± 1.2) d of age. Each pen in this facility was fitted with a single drinker nipple and a feeder and enrichment toy (Porcichew; Otto Environmental, Greenfield WI, USA) attached to the front wall of each pen. All pigs were individually weighed at entry to the facility (35 d after weaning), 3 weeks after entry (56 d after weaning), 6 weeks after entry (77 d after weaning) and at sale (either 98 or 105 d after weaning; 135 ± 3.6 d of age). Pigs were sold to achieve a target market weight and hence were sorted and sold over 2 weeks (n = 35 pigs sold 98 d after weaning and n = 62 sold 105 d after weaning).

2.6 Collection of carcass data at abattoir

Pigs were individually branded at sale so they could be identified at an on-site abattoir. On day of sale, pigs were transported to the abattoir via truck and stayed in lairage overnight to be processed the next day. Each carcass was weighed to obtain the hot standard carcass weight (HSCW), and backfat (P2) and loin depth (LD) were measured at the P2 site on each carcass using a Hennessy Grading Probe (Hennessy Grading Systems, Auckland NZ). For each pig, dressing percentage (DP, %) was calculated as the live BWT of the animal divided by the HSCW * 100.

A new binary variable (%Prime; Yes or No) was set up to capture the number of carcasses that would be considered in the prime grid specification for a large commercial customer. The grid used classified a prime carcass as those which were between 65 and 85 kg HSCW and with <13 mm backfat at the P2 site, with penalties for carcasses falling outside these specifications. Grid specifications used were those current as of 3rd of October 2023. A carcass value (AUD) was also calculated for each pig based on this grid, current penalties and HSCW.

2.7 Laboratory analysis of immunocrit

Immunocrit was measured in each piglet blood sample using the technique of Vallet et al. (2013). Briefly, 100 µL of thawed serum was combined with 100 µL of 40% $(NH_4)_2SO_4$ to form a precipitate. For each sample, a background solution was prepared by mixing 100 µL of serum with 100 µL of distilled water. The samples were then added to 70 µL microcapillary tubes (non-heparinised) and centrifuged in a haematocrit centrifuge at 12,700 x *g* for 10 min. The immunocrit ratio (%) was calculated by diving the length precipitate in the tube by the length of solution and subtracting the value from the background tube.

2.8 Statistical analyses

All statistical analyses were carried out using SPSS (version 27; IBM, Armonk NY, USA). For all continuous traits linear mixed modelling analysis was performed, blocked by replicate, with sow diet as a fixed factor and birth litter as a random factor when piglet was the experimental unit to account for any common litter effects where possible. Pairwise comparisons were made between treatment groups using the LSD method. This analysis was performed using the MIXED procedure of SPSS. Categorical binary variables (e.g., FR, %Prime) were analysed using chi-square (X^2) analysis.

Sows were grouped into three categories based on their parity at mating: parity 1 (n = 99), parity 2 (n = 111) and parity 3+ (n = 107), and this parity group was fitted as a fixed factor. The parity group x diet interaction was also fitted and only left in the model where it made a significant ($P < 0.05$) contribution. Parity was originally tested as a dependent continuous variable and found to be not significantly different between dietary treatment groups ($P = 0.87$; data not shown).

Birth weight significantly influenced growth parameters after weaning when tested as a covariate ($P \leq 0.10$); however, dietary treatment effects did not change when this was added to the model and hence the results from these models have not been presented. Weaning age was not significantly different between treatments ($P \geq 0.10$) and did not significantly influence the model when included as a covariate for post-weaning growth traits. Hence, weaning age was left out of the model.

In the weaner period, 1 pig (MED) lost weight 8 d after weaning, was unwell and required treatment, and was euthanised shortly after. This pig was not included in the analysis for this period. In the grower-finisher period, a number of pigs were caught wasting a significant amount of feed, which would impact their calculated ADFI. Therefore, any feed intake data (and the resultant ADFI and FCR) was not included in the analysis for these animals from the point that the pigs were observed wasting feed (CON: n = 4; SHORT: n = 3; MED: n = 1; LONG: n = 8; from 0, 21, 42 or 63 d onwards), or for the whole grower-finisher period.

3. Outcomes

3.1 Sow and litter performance

Number of days from entry to the farrowing house was not significantly different between dietary treatments ($P = 0.44$), nor was gestation length (116.0 ± 1.53 d; $P = 0.80$) or lactation length ($P = 0.66$, data not shown).

There was no significant influence of CAN supplementation period on FR ($P = 0.15$; data not shown). At d 92 there tended to be an impact of diet on sow BWT ($P = 0.072$) where CON sows were lightest, LONG sows heaviest, and SHORT and MED sows were intermediate (data not shown). However, these differences were not present at mating ($P = 0.37$), d 108 ($P = 0.72$) or at weaning ($P = 0.46$). Given that CON and SHORT sows were treated equally up until this point, this difference was most likely due to individual variation between sows and less likely due to dietary treatment.

Body weight change (Fig. 1) and P2 backfat change (Fig. 2) in gestation were significantly influenced by sow CAN supplementation ($P = 0.046$ and $P < 0.001$, respectively). For BWT change, SHORT sows lost the most BWT in gestation and MED sows lost the least. A similar effect was seen for P2 change. There tended ($P = 0.079$) to be a difference in P2 backfat between the four dietary treatment groups at mating, where P2 was numerically lower in CON (15.9 ± 0.34 mm) and SHORT (15.6 ± 0.34 mm) sows compared to MED (16.5 ± 0.33 mm) and LONG sows (16.6 ± 0.34 mm). This may have contributed to the differences seen in body weight and P2 changes over gestation; however, BWT ($r = -0.12$; $P = 0.074$) and P2 change in gestation ($r = -0.31$; $P < 0.001$) showed weak correlations with P2 backfat level at mating. There were no differences in P2 backfat at d 92 or d 108 of gestation ($P =$

0.18 and 0.21, respectively; data not shown). The commercial relevance of this finding is currently unclear and deserves further investigation.

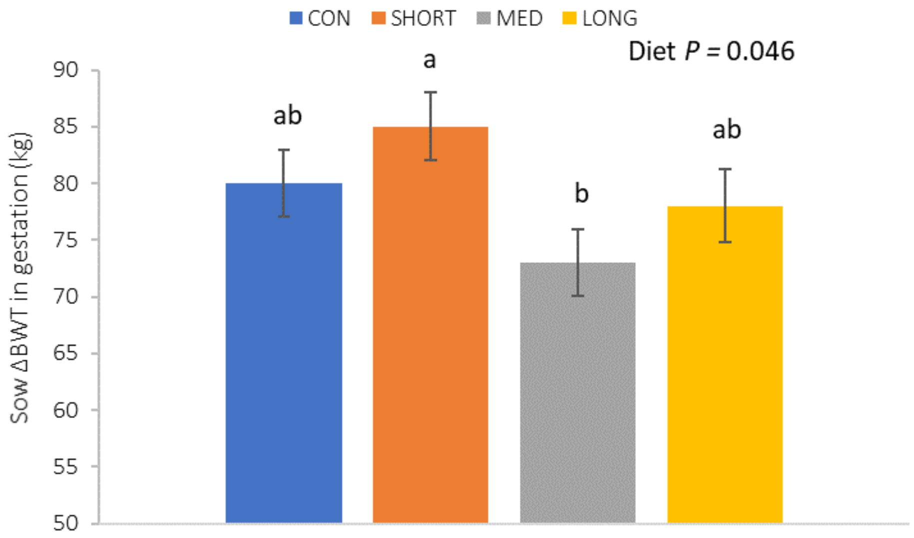

Fig. 1: Least square means (± SEM) showing the impact of sow dietary treatment (CON vs. short, medium or long-term CAN supplementation) on sow body weight change (ΔBWT) in gestation. ^{ab}Different superscripts denote significant pairwise differences between dietary treatments ($P < 0.05$).

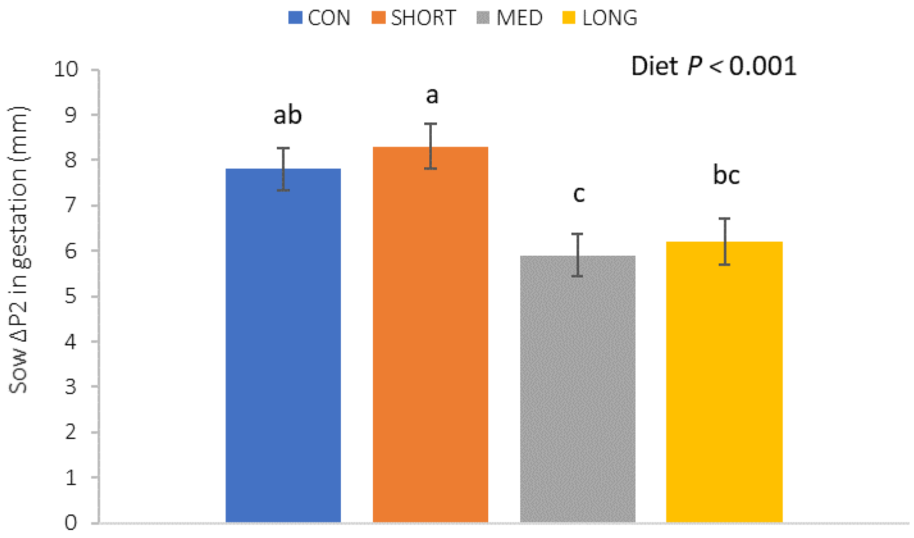

Fig. 2: Least square means (± SEM) showing the impact of sow dietary treatment (CON vs. short, medium or long-term CAN supplementation) on sow P2 backfat change (ΔP2) in gestation. ^{abc}Different superscripts denote significant pairwise differences between dietary treatments ($P < 0.05$).

There was no difference in sow weight loss in lactation between CON (-23 ± 2.4 kg), SHORT (-27 ± 2.4 kg), MED (-21 ± 2.3 kg) or LONG sows (-22 ± 2.5 kg; *P* = 0.35), nor was there a difference in change in P2 backfat in lactation (-2.4 ± 0.44 mm, -3.0 ± 0.44 mm, -3.0 ± 0.42 mm and -2.2 ± 0.46 mm, respectively; *P* = 0.47). There tended to be a difference in sow P2 backfat at weaning between the four dietary treatments (*P* = 0.063) where MED sows had the lowest P2 (19.2 ± 0.46 mm) compared to the other treatments. This was also the case at d 108 when sows entered the farrowing house; however, the difference between MED sows (22.3 ± 0.49 mm) and the other sows was only numeric at this timepoint (*P* = 0.21) but may explain why there tended to be a difference at weaning.

There was no effect of CAN supplementation period on piglets BA, stillborn, proportion of stillborn piglets or TB (*P* ≥ 0.10; Table 1). There was no significant impact of sow CAN supplementation on the proportion of liveborn piglets born weighing <1.1 kg (*P* = 0.99), BWT CV (*P* = 0.99) or piglet immunocrit at 24 h (*P* = 0.36; data not shown). Litter weight at birth (live piglets) or at d 21 was not significantly influenced by CAN supplementation (*P* ≥ 0.10; Fig. 3). Similarly, there was no effect of CAN supplementation on average piglet BWT (of piglets born alive) at these timepoints (*P* ≥ 0.10; Fig. 4). There was no influence of sow CAN supplementation on litter weight or average BWT of piglets after fostering (*P* ≥ 0.10; data not shown).

Table 1: Impact of duration of calcium nitrate (CAN) treatment of sows in gestation (SHORT = d 108 of gestation until farrowing; MED = from d 92 of gestation until farrowing; LONG = from d 2 of gestation until farrowing) on litter performance. Estimates presented as least square mean ± SEM.

	Sow Dietary Treatment				**Diet**
	CON	**SHORT**	**MED**	**LONG**	***P*-value**
BA	11.1 ± 0.54	11.0 ± 0.53	10.6 ± 0.52	11.0 ± 0.58	0.90
SB	0.7 ± 0.14	0.7 ± 0.14	1.0 ± 0.14	0.6 ± 0.15	0.15
%SB (%)	5 ± 1.4	6 ± 1.3	9 ± 1.3	6 ± 1.5	0.28
TB	11.9 ± 0.58	12.0 ± 0.58	11.9 ± 0.56	11.7 ± 0.63	0.99

BA = born alive (pigs per litter); SB = stillborn (pigs per litter); TB = total born (pigs per litter); %SB = percentage of piglets born stillborn per litter (as a proportion of TB).

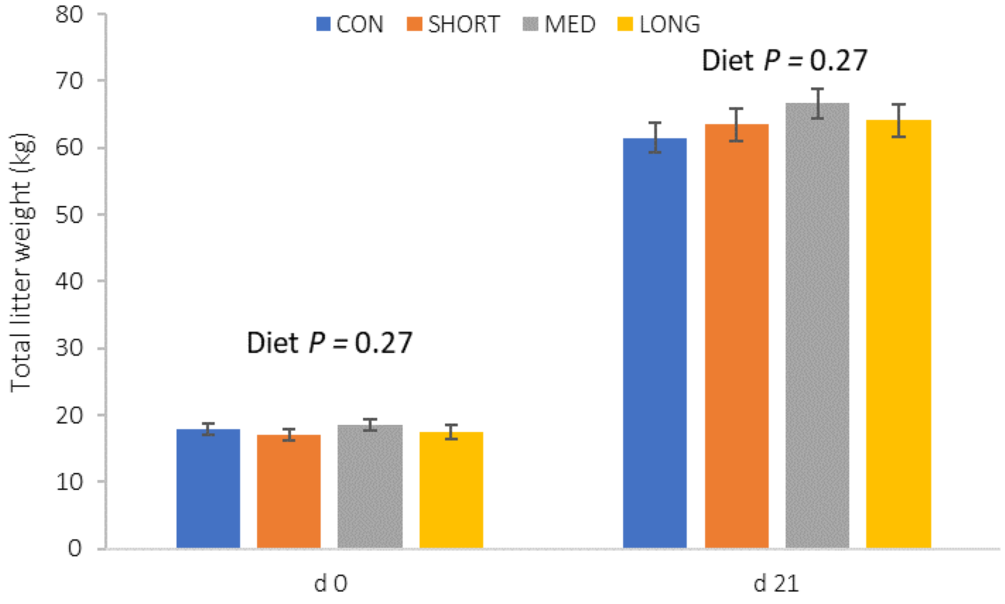

Fig. 3: Least square means (± SEM) showing the impact of sow dietary treatment (CON vs. short, medium or long-term CAN supplementation) on litter weights at d 0 (piglets born alive) and d 21 of lactation.

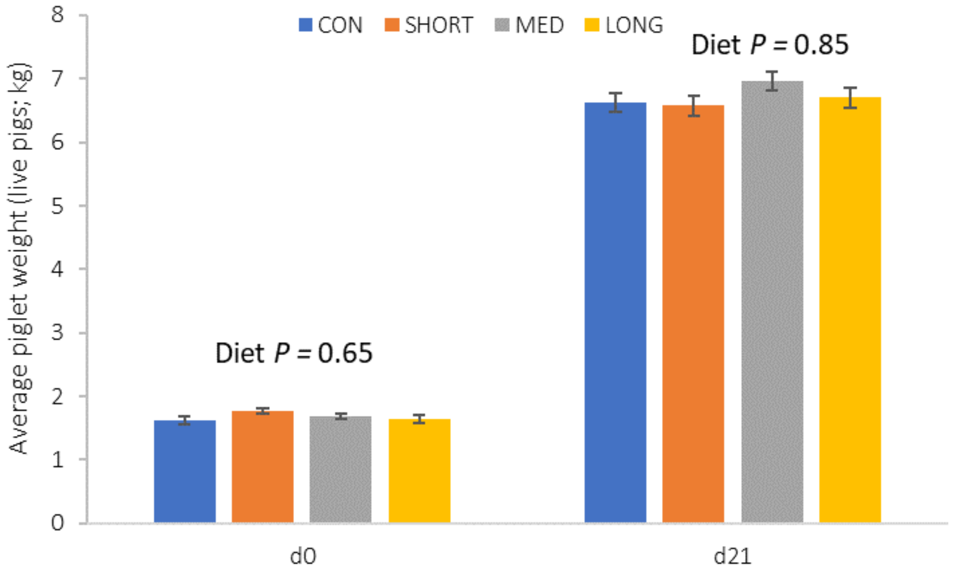

Fig. 4: Least square means (± SEM) showing the impact of sow dietary treatment (CON vs. short, medium or long-term CAN supplementation) on average piglet weight at d 0 (piglets born alive) and d 21 of lactation.

These results are in disagreement to those found in previous studies (van den Bosch et al., 2019a,b; 2021) where the incidence of stillborn piglets was found to be reduced and/or piglet vitality and BWT at birth was increased with sow CAN supplementation. Those studies were conducted in hyperprolific sows where litter sizes are much higher than they are in the current experiment, and hence stillbirth rate was much higher overall in these previous studies. This may explain the findings in these studies and the lack of difference in stillbirth rate in our study. The authors (van den Bosch et al., 2021) stated that it is common to feed sows either 2 or 3 meals per day before farrowing in the EU where that study was conducted; whereas, in the commercial herd used in the current study, sows are only fed once per day before farrowing. The number of meals given to sows before farrowing has been known to influence the incidence of stillbirths (Tucker et al., 2022), and hence this may also be a reason why differences were seen in our study compared to previous studies. This relationship between number of meals per day before farrowing and CAN supplementation deserves further investigation, as this may depend on the timeline of CAN action within the placenta to influence the development and hence survival of the piglets.

There was no impact of CAN supplementation period on the number of piglets in the litter at d 21 (*P* = 0.85; data not shown). Sow ADFI in lactation was significantly influenced by CAN supplementation period (*P* < 0.001) where CAN sows ate more feed per day than those in the CON group (Fig. 5). However, the additional lactation feed intake of sows did not result in an increase in piglet weight close to weaning (measured at day 21), as described above. This increase in feed intake of sows without improvement in performance would represent an additional cost to the producer. There was no significant impact of CAN supplementation period on the number of sows removed throughout the duration of the experiment, either in gestation or lactation (*P* ≥ 0.10; data not shown).

Piglet mortality was not significantly influenced by sow CAN supplementation period, either before fostering (*P* = 0.65) or after fostering until weaning (*P* = 0.75; Fig. 6). Piglet pre-weaning mortality rate (after fostering) was numerically lower in the CAN treatments; however, this was highly variable between litters, and there was likely insufficient power to detect dietary effects.

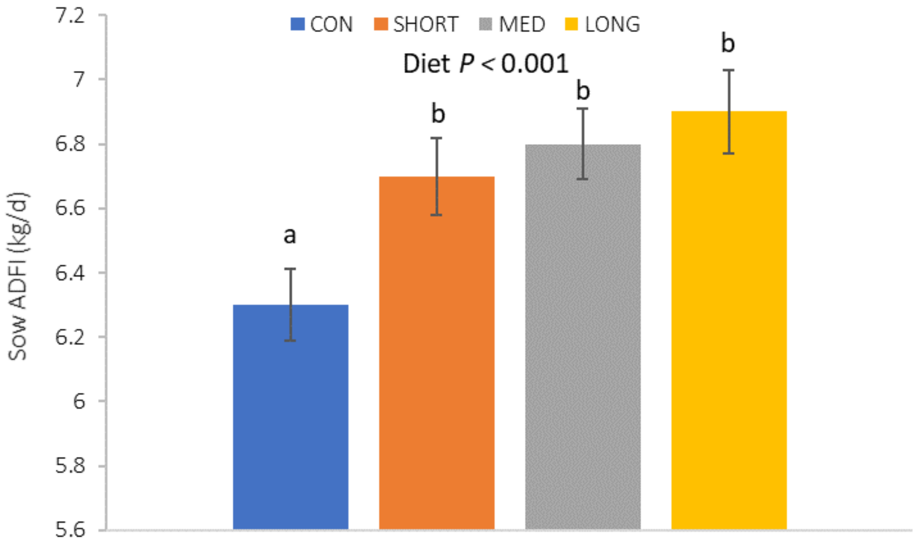

Fig. 5: Least square means (± SEM) showing the impact of sow dietary treatment (CON vs. short, medium or long-term CAN supplementation) on sow average daily feed intake (ADFI) in lactation. ^{ab}Different superscripts denote significant pairwise differences between dietary treatments ($P < 0.05$).

The lack of effect of CAN supplementation on piglet survival in the current study could have been due to the rigorous farrowing supervision and piglet drying procedures employed at the commercial farm where this study was conducted. Indeed, van den Bosch et al. (2019b) found that piglet vitality was improved around birth, with piglets born to CAN supplemented sows having higher concentrations of pO_2 in umbilical cord blood, which they suggested may be indicative of a shorter interval between birth and respiration of these piglets. Hence piglets were more likely to survive with increasing nitrate supplementation in their study. However, in the current study, the advantages of this increased vitality may have been negated by the physical drying, warming, and placement at the udder of piglets. Unfortunately, it was not recorded which litters received additional supervision and care during farrowing in the current experiment to be able to carry out a comparison. However, this would be interesting to further investigate in future studies.

In a follow up study, van den Bosch et al. (2021) found no influence of sow CAN supplementation on piglet mortality rates before weaning and speculated that this may have been due to commercial fostering procedures employed during that study to increase uniformity of litters soon after birth. This was potentially an influencing factor in our study as well.

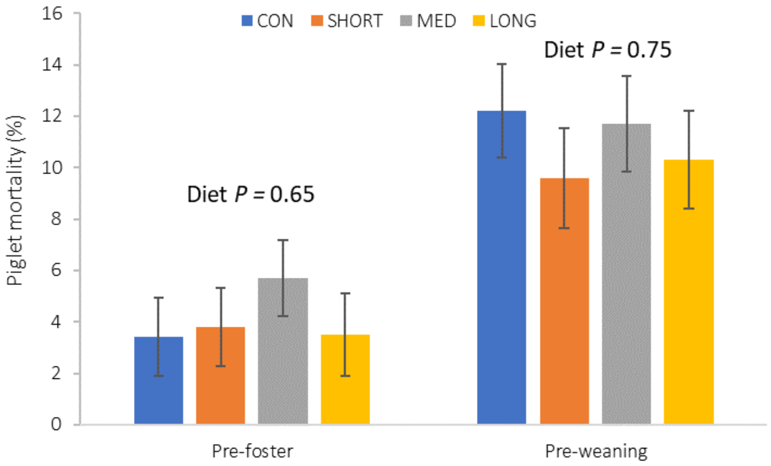

Fig. 6: Least square means (± SEM) showing the impact of sow dietary treatment (CON vs. short, medium or long-term CAN supplementation) on piglet mortality before fostering (as a % of BA) and before weaning (as a proportion of litter size after fostering).

3.2 Subsequent reproductive performance

Wean to remate interval (WRI) tended to differ between sow dietary treatment (*P* = 0.065) where MED sows had a shorter WRI (4.2 ± 0.13 d) than LONG sows (4.7 ± 0.16 d) with the CON (4.5 ± 0.15 d) and SHORT (4.4 ± 0.15 d) sows intermediate. Subsequent FR was not impacted by CAN supplementation (*P* = 0.50), nor were subsequent BA (*P* = 0.76) or TB (*P* = 0.31, data not shown). However, there was a significant interaction between dietary treatment and parity group for subsequent BA (*P* = 0.010; Fig. 7A) and subsequent TB (*P* = 0.004; Fig. 7B).

Total born was significantly higher in CON parity 1 sows compared to MED and LONG parity 1 sows (*P* < 0.05); however, BA was only significantly different between CON and MED parity 1 sows (Fig. 7). Regardless, all CAN treatment parity 1 sows had numerically higher BA and TB than CON parity 1 sows. There were no significant differences between any of the dietary treatments in terms of BA or TB in parity 2 sows. Conversely, in parity 3+ sows, CON sows had significantly higher BA and TB than SHORT and MED parity 3+ sows. The difference between CON and LONG parity 3+ sows was not significant; however, LONG sows had a numerically lower BA and TB (Fig. 7).

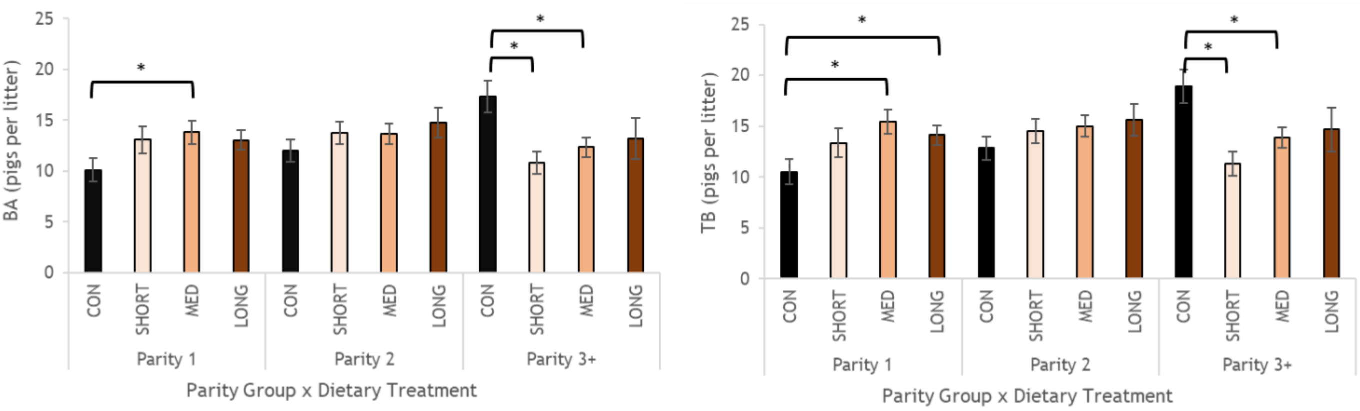

Fig. 7: Least square means (± SEM) showing the interaction between parity group (1, 2, 3+) and dietary treatment (CON vs. short, medium or long-term CAN supplementation) on pigs born alive (BA; A) and total born (TB; B) in the subsequent litter after CAN supplementation. *Indicates a significant (*P* < 0.05) pairwise difference between 2 groups.

Reasons for these interactions are unclear from the outcomes of the current study; however, this could have been impacted by the high proportion of sows culled or that had a mating skipped after weaning to accommodate converting to the batch system at the commercial farm. Regardless, interactions between sow parity and performance with CAN supplementation before farrowing deserves to be further studied. It may well be that CAN supplementation has the highest benefit for younger (parities 1 and 2) and older parity sows (e.g., parity 7+) where uterine space may be limited, younger parity sows due to immaturity and older parity sows due to larger litter sizes. However, the commercial implications of treating these sows differently before farrowing needs to be carefully considered.

3.3 Progeny performance

Growth performance of progeny followed after weaning to slaughter is shown in Table 2. There was no difference in BWT at birth (*P* = 0.80) or at d 21 of lactation for the cohort of pigs that were selected for the individual housing facilities to be followed after weaning (*P* = 0.74; data not shown). There was also no significant difference in weaning age between dietary treatments (*P* = 0.38; data not shown). There were no significant differences in BWT between CAN treatments at any experimental timepoint in the weaner or grower-finisher phases (*P* ≥ 0.10). There were no significant effects of diet on ADG, ADFI or FCR during any of the growth periods during the weaner phase (*P* ≥ 0.10; Table 2).

One pig died in the weaner period on d 8 after weaning (MED) due to destruction for ill-thrift. In the grower-finisher period, one CON pig was destroyed due to a rectal prolapse on d 56 after weaning and one MED pig died suddenly (cause unknown) between d 56 and 77 after weaning. There were no other mortalities throughout the post-weaning period and hence not enough power to detect differences in post-weaning mortality between the different CAN treatments.

There were no significant effects of diet on ADFI or FCR during any of the growth periods studied in the grower-finisher period ($P \geq 0.10$; Table 2). There was a significant impact of diet ($P = 0.031$) on ADG in the last week before sale for those that were sold 15 weeks after weaning, where LONG pigs grew significantly ($P < 0.05$) slower than the pigs in other treatments (data not shown); however, this only represented half of the cohort of pigs ($n = 63$) as the others were sold 14 weeks after weaning, and the biological meaning of this finding is unclear.

Table 2: Impact of duration of calcium nitrate (CAN) treatment of sows in gestation (SHORT = d 108 of gestation until farrowing; MED = from d 92 of gestation until farrowing; LONG = from d 2 of gestation until farrowing) on lifetime performance of progeny up until sale, taken from a cohort of experimental pigs selected at weaning (*n* = 100). Estimates presented as least square mean ± SEM.

	Sow Dietary Treatment				
	CON	**SHORT**	**MED**	**LONG**	**Diet *P*-value**
Weaner period					
d 0 (weaning) BWT (kg)	9.2 ± 0.49	10.4 ± 0.48	9.8 ± 0.47	10.5 ± 0.51	0.21
d 7 BWT (kg)	10.7 ± 0.54	11.4 ± 0.53	11.0 ± 0.51	11.9 ± 0.56	0.49
d 28 BWT (kg)	22.7 ± 0.93	22.8 ± 0.91	22.3 ± 0.89	22.8 ± 0.97	0.98
ADG (g/d)	549 ± 23.0	526 ± 22.8	534 ± 22.3	519 ± 23.6	0.81
ADFI (g/d)	725 ± 37.3	698 ± 36.2	686 ± 35.1	725 ± 38.7	0.83
FCR (g:g)	1.3 ± 0.03	1.3 ± 0.03	1.3 ± 0.03	1.4 ± 0.03	0.29
Grower-finisher period					
d 35 BWT (kg)	28.4 ± 1.11	28.7 ± 1.09	28.4 ± 1.06	28.7 ± 1.15	0.99
d 98 BWT (kg)	98.3 ± 2.83	97.7 ± 2.73	97.5 ± 2.74	99.1 ± 2.91	0.98
*d 105 BWT (kg)**	101.4 ± 2.42	103.0 ± 2.18	100.5 ± 2.34	104.2 ± 2.00	0.64
*ADG (kg/d)**	1.11 ± 0.023	1.13 ± 0.022	1.13 ± 0.022	1.13 ± 0.023	0.90
*ADFI (kg/d)**	2.60 ± 0.075	2.62 ± 0.074	2.50 ± 0.072	2.71 ± 0.081	0.28
*FCR (kg:kg)**	2.35 ± 0.054	2.31 ± 0.054	2.20 ± 0.052	2.40 ± 0.059	0.083

ADG = average daily gain, ADFI = average daily feed intake, FCR = feed conversion ratio.

*Corrected for age at sale (d 135) as a covariate.

3.4 Carcass quality and the bottom line

There was no significant difference between dietary treatments in %Prime (*P* = 0.77). Overall, 43.5% of carcasses were within prime specifications, 43.5% for CON pigs, 34.8% for SHORT pigs, 45.8% for MED pigs and 50.0% for LONG pigs. There were no significant effects of diet (*P* ≥ 0.10) on any of the other carcass parameters studied (Table 3).

Table 3: Impact of duration of calcium nitrate (CAN) treatment of sows in gestation (SHORT = d 108 of gestation until farrowing; MED = from d 92 of gestation until farrowing; LONG = from d 2 of gestation until farrowing) on carcass parameters of progeny at sale. Estimates presented as least square mean ± SEM.

	Sow Dietary Treatment				**Diet**
Variable	**CON**	**SHORT**	**MED**	**LONG**	***P*-value**
Live BWT (kg)*	102.8 ± 1.75	105.2 ± 1.71	104.8 ± 1.72	105.6 ± 1.76	0.68
Live P2 (mm)*	11.3 ± 0.33	11.2 ± 0.32	10.6 ± 0.32	11.3 ± 0.33	0.36
HSCW (kg)*	75.8 ± 1.49	77.8 ± 1.44	77.2 ± 1.43	78.8 ± 1.55	0.57
Carcass P2 (mm)*	13.3 ± 0.58	13.6 ± 0.57	12.3 ± 0.57	13.5 ± 0.59	0.38
Corrected P2 (mm)†	13.4 ± 0.47	13.7 ± 0.46	12.4 ± 0.45	13.2 ± 0.48	0.19
LD (mm)*	53.6 ± 1.13	53.2 ± 1.11	53.4 ± 1.11	53.3 ± 1.17	1.00
Corrected LD (mm)†	54.0 ± 1.11	53.2 ± 1.07	53.4 ± 1.06	52.6 ± 1.15	0.84
Ave grid price ($/kg)	3.91 ± 0.103	3.85 ± 0.103	3.93 ± 0.101	3.91 ± 0.105	0.96
Carcass value ($)	296 ± 7.9	300 ± 7.9	304 ± 7.7	305 ± 8.0	0.83

BWT = body weight; HSCW = hot standard carcass weight; LD = carcass loin depth at the P2 site; P2 = backfat thickness at the P2 site.

*Corrected for age at sale (d 135 ± 3.6) as a covariate. †Corrected for HSCW (77.5 ± 6.41 kg) as a covariate as well as age at sale.

To the best of our knowledge, this is the first study to examine the impact of supplementation of CAN to sows before farrowing on progeny performance to slaughter. From the results seen in this study it seems that sow CAN supplementation before farrowing does not influence progeny performance to slaughter, regardless of supplementation period. However, it is important that these results be repeated in a commercial setting with a larger sample size. The limited sample size in the current study may have not been enough to detect any effects on post-weaning performance. Moreover, the individual intensive facilities used in this project may have resulted in improved health conditions and supervision of pigs allowing for better health status in these animals compared to those housed in a commercial system.

4. Application of Research

Results from the current project suggest that supplementing CAN to sows in gestation, either short-, medium- or long-term would not be a beneficial strategy for producers to use to improve their herd performance, especially considering the additive would come at an additional cost.

The findings that sows supplemented with CAN from d 92 of gestation until farrowing did not reduce the proportion of piglets born <1.1 kg, birth weight variation within litters or pre-weaning mortality rates was inconsistent with findings from our previous study (APRIL project 5A-104). In that project we found that CAN supplementation to sows from d 90 of lactation significantly improved the proportion of piglets born <1.1 kg and survival to weaning compared to a diet including supplemental ARG. However, these measures were analysed by chi-square analysis in a 5-way treatment comparison in that study. It may have been that most of the treatment effect seen in that study in terms of piglet birth weight was due to differences between the CAN and ARG diets, rather than between the CAN and the control diet. Similarly, for piglet post-foster mortality rates in that study, the significant chi-square result may have been influenced by the larger difference in mortality between CAN sows and sows fed another additive tested in that study (ß-hydroxy ß-methyl butyrate; HMB), rather than between CAN and control sows. The same CAN product (Ixom, East Melbourne, Vic, Australia) was used in both the current study and the previous one.

Sows of older parities (9 and 10) were included in our previous study (averaging 3.8) whereas only sows up to parity 8 were included in the current study (averaging 2.5). It is likely that a higher proportion of piglets from the older parity sows could have been born <1.1 kg and therefore CAN supplementation may have more of a significant effect on the birth weights of piglets from these sows. Furthermore, there may have been a seasonal effect creating differences between studies (winter vs. autumn farrowings in our previous study).

Another reason for differences between the two studies could be that extended pig care at farrowing was employed on the farm when the current study was conducted, which was not the case during project 5A-104. The extra care given to the piglets around farrowing may have negated the positive impact of improved viability of piglets by provision of CAN to their dams.

Therefore, CAN may still be an alternative to supplemental ARG in sow diets when supervision around farrowing times is not possible, to potentially improve piglet vitality.

4.1 Storage Concerns

The CAN product we used for the current study, when stored at the commercial feed mill for a long period of time after the project was finished, caused corrosion of the metal storage cabinet where it was located (Fig. 8). Stability of feed-grade CAN products, correct storage at feed mills and potential impacts on silos and other infrastructure is therefore an important consideration if long-term use of CAN in sow feeds is to be considered.

Fig. 8: Corrosion of metal surface at Corowa feed mill after long term storage of calcium nitrate product.

5. Conclusion

In conclusion, supplementation of CAN in sow diets did not significantly influence piglet birth weights, birth weight variation or survival to weaning when fed either short, medium, or long term in pre-farrowing sow diets in the current study and we therefore reject our original hypothesis. Furthermore, piglet growth performance to slaughter was not improved when their dams were provided with CAN in their pre-farrowing diets.

6. Limitations/Risks

It is important that the commercial conditions of the current study be considered when interpreting the outcomes of this project. Under the conditions of this particular study, CAN supplementation in sow diets in gestation did not improve sow or piglet performance:

- When farrowing supervision was adequate and piglets were dried and placed at the udder soon after birth;
- In sows of parities 1 to 8 at mating;
- Compared to sows not supplemented with ARG; however, results from project 5A-104 previously suggested that CAN is preferable to ARG in sow diets to improve piglet birth weights and survival chance to weaning.

As discussed above, incorrect storage of CAN at the feed mill or on farm may cause storage issues if the product used is not shelf-stable. Therefore, this additive needs to be stored correctly and routinely checked if stored for long periods. However, the safety of feeding this product in sow diets at the low inclusion of 0.1% has been confirmed in a number of recent studies (Doepker et al., 2021; van de Ligt et al., 2021).

7. Recommendations

As a result of the outcomes in this study the following recommendations have been made:

a) Calcium nitrate included at 0.1% in sow diets, fed either short- (from entry to the farrowing house), medium- (from approx. d 92), or long-term (throughout all of gestation) before farrowing, cannot be recommended for use under commercial conditions corresponding to those used in this experiment.
b) If CAN is to be used in sow diets, storage of the product at feed mills and its stability in sow diets needs to be carefully considered.

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