RESEARCH REPORT
ANIMAL WELFARE

Title: Regulating Feed Intake of Group Housed Replacement Gilts by Altering Dietary Cation/Anion Difference – NPB #10-042 Revised

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Industry Summary:

The swine industry is currently facing an enormous amount of public pressure to eliminate the use of individual gestation stalls in favor of group housing for gestating sows. Since over consumption of feed is a common problem in gestating sows, there is a need for development of an inexpensive, low-maintenance feeding system that can limit feed intake of the sow while still providing all essential nutrients. Most aggressive behavior of group-housed sows occurs during feeding. Allowing sows *ad libitum* access to feed may decrease aggression and improve sow welfare. The use of self-feeders could be an ideal option for producers utilizing group-housed gestation systems; however, over-consumption of feed may be a problem. Decreasing dietary cation-anion difference (DCAD) by the addition of ammonium chloride or calcium chloride has been shown to decrease feed intake in pigs and may be useful in the development of a simple feeding strategy that reduces excessive feed intake of *ad libitum* fed gestating sows housed in groups. The objective of this pilot study was to determine the most efficacious dietary cation-anion level that will allow mature gilts to self-regulate their feed intake when fed *ad libitum* in group housing.

Ninety, six to nine month-old crossbred gilts (Duroc x Chester White x Yorkshire) were used in this study. The gilts weighed approximately 284 pounds, were housed in groups of five per pen and were offered one of three dietary treatments *ad libitum* for 45 days. Gilts were blocked by weight and randomly assigned within block to treatment pens. Treatment pens were equipped with one self feeder located over slotted floors. After a preliminary week of feeding a standard finisher diet, diets were randomly assigned to treatment pens (two pens/diet). This procedure was repeated in each of three trials (30 gilts/trial). The treatment diets consisted of one of the following levels of DCAD: 50 (control), -225, or -450 mEq/kg diet, and the gilts were fed their respective diet *ad libitum* for 45 days. All diets met or exceeded the nutritional requirements indicated by the NRC (1998). Water intake was not restricted. All diets were corn- and soybean meal-based, and DCAD levels

were lowered by the addition of ammonium chloride. Calcium content was kept constant across treatments by the addition of calcium sulfate. Gilt weights and ultrasound backfat measurements were taken every week. Feed disappearance was recorded at these times by weighing pen feeders. Room temperatures were maintained between 22 and 29 ºC and gilts were monitored daily for feed intake, as well as general well-being. Any wet feed was removed daily from the feeder, weighed, and a sample was kept for dry matter analysis. Dietary cation-anion difference had a direct linear relationship with average daily feed intake (as DCAD became more negative feed intake decreased). The -225 treatment did not affect BW, ADG, gain/feed, backfat, or blood pH when compared to control gilts. However a significant reduction in urine pH was observed for this treatment. While -225 DCAD resulted in reduced feed intake during the first two weeks, gilts became accustomed to the diet and increased feed intake over the remaining four weeks. The -450 treatment resulted in significantly reduced BW, ADG, gain/feed, and urine pH when compared to control gilts for the entire 45 day period. There were trends for blood pH and backfat gains to decrease with decreasing DCAD. The results of this study suggest that decreased DCAD may be a useful tool in regulating feed intake of group-housed gilts, effectively suppressing feed intake with no apparent negative effects on body condition or general well-being.

The -225 DCAD treatment did not have the desired effect on reducing feed intake and weight gain in group-housed gilts over a sustained period of time. The -450 treatment did effectively suppress feed intake and weight gain with no observable negative side effects. However, by the end of week 6 average daily feed intakes of the -450 treatment were approaching the control diet intakes. Results from this study indicate that the addition of chloride to swine diets may be an effective strategy to decrease feed intake, while maintaining body condition and nutrient digestibility. This is of particular use in gestating sow diets, where producers have modified gestation housing to group housing and need an economic method for feeding the sows. This study observed the effects of added dietary chloride on gilts only, and although no negative side effects on body condition, nutrient digestibility, or skeletal integrity were noted over the course of the trial, prolonged induced metabolic acidosis may eventually lead to clinically detrimental side effects. This study fed altered DCAD for 45 days. If gestating sows are housed in stalls until pregnancy is verified at 35 days, then group housed until day 110 of gestation when sows are moved into farrowing stalls, DCAD must be maintained for 75 days or 11 weeks. Longer trials are needed in order to determine the extent of acclimation of DCAD treatment. Further research is needed in order to determine whether or not similar effects would be observed in gestating sows if fed similar diets over the course of gestation.

Keywords: Loose housing, sows, limiting intake, self fed, Gilts

Scientific Abstract:

Group housing for gestating sows is becoming increasingly prevalent, necessitating the development of efficient and easily-managed group feeding systems. The use of self-feeders could be an ideal, low cost, low maintenance option for producers utilizing group-housed gestation systems; however, over-consumption of feed may be a problem. Dietary cation-anion difference (**DCAD**) has previously been shown to reduce feed intake. This study observed the effects of DCAD on feed intake of group-housed gilts, as well as other performance characteristics and nutrient digestibility. Ninety, six to nine month-old gilts were used in this study. Gilts were housed in groups of five per pen and offered one of three dietary treatments *ad libitum* for 45 days. Gilts were blocked by weight and randomly assigned within block to treatment pens. Diets were randomly assigned to treatment pens (two pens/diet). This procedure was repeated in each of three trials (30 gilts/trial). The treatment diets consisted of one of the three levels of DCAD (MEg/kg diet): control (50), treatment 1 (-225) and

treatment 2 (-450). Weekly feed disappearance, BW, backfat, urine and blood pH measurements were recorded for each trial. Feed and fecal samples were collected and analyzed for DM, nitrogen, and energy digestibility. Average daily feed intake decreased ($P \leq 0.05$) with decreasing DCAD. No significant differences in BW, BW gain or G/F were observed between control and -225, but -450 resulted in lower ($P \leq 0.05$) BW, BW gain and G/F. No significant differences between treatments in DM and energy digestibility or blood pH were observed. Urine pH decreased ($P \leq 0.05$) as DCAD decreased and N digestibility was higher for -225 and -450 than 50. Results of this study indicate that decreasing DCAD may serve as an effective method for limiting ADFI of self fed sows in group housing.

Key Words: Group Housing, Sows Self Fed, Gilts

Introduction:

The swine industry is currently facing an enormous amount of public pressure to eliminate the use of individual gestation stalls in favor of group housing for gestating sows. Since over consumption of feed is a common problem in gestating sows, there is a need for development of an inexpensive, low-maintenance feeding system that can limit feed intake of the loose housed sow while still providing all essential nutrients. Most aggressive behavior of group-housed sows occurs during feeding (Levis, D.G. 2007). Several methods of limit feeding loose housed sows are available to swine producers. These methods include: electronic feeders, floor feeding, half stall feeding and full stall feeding. Electronic stalls allow for individual sow access and individual regulation of feed intake. Electronic feeding stalls are expensive and require more intense maintance. Floor feeding is economical but requires at least a portion of the floor to be solid and can result in excessive sow aggression during feeding. Full feeding stalls can result in individual sow feeding and less fighting during feeding but can require more labor during feeding and are more expensive than floor feeding. One-half stalls require less labor but may not prevent aggression during feeding and limit the potential to individually feed sows. Allowing sows *ad libitum* access to feed may decrease aggression and improve sow welfare. The use of self-feeders could be an ideal option for producers utilizing group-housed gestation systems; however, over-consumption of feed may be a problem. Decreasing dietary cation-anion difference (DCAD) by the addition of ammonium chloride or calcium chloride has been shown to decrease feed intake in pigs (Yen et al., 1981) and may be useful in the development of a simple feeding strategy that reduces excessive feed intake of gestating sows-- particularly when they are housed in groups.

The mechanism by which low DCAD decreases feed intake is not fully understood, but metabolic acidosis may play a part in depressing appetite (Yen et al., 1981). Several other physiological changes, including decreased urine and blood pH, mobilization of calcium, and decreased water intake have been observed to accompany the decrease in feed intake induced by decreased DCAD (Rude and Rankins, 1997; Dersjant-Li et al., 2001_a). The extent to which these factors negatively affect full-grown pigs has not been extensively studied. Observing the effects of a diet with low DCAD on gilts before applying the ideas to gestating sows decreases the risk of severe negative effects on sow well-being. If successful, lowering DCAD could be an extremely simple and effective way of regulating feed intake of gestating sows.

Objectives:

Our hypothesis was that lowering the DCAD would decrease feed intake and weight gain without negatively affecting gilt physical well-being while maintaining optimum body condition.

Therefore, the objectives of this study were to formulate a diet that will allow group-housed gilts to regulate their feed intake to approximately 2.5 kg/gilt/day by varying DCAD, as well as to determine dietary apparent DM, nitrogen, and energy digestibility.

Materials and Methods:

This project was approved by the Illinois State University Institutional Animal Care and Use Committee, protocol number 10-2010. Ninety, six to nine month-old crossbred gilts (Duroc x Chester White x Yorkshire) gilts that weighed approximately 125 kg were used in this study. Gilts were housed in groups of five per pen. Pens were 126 square feet and each was equipped with a drop feeder measuring 12" deep x 36" high x 42" wide (4.72 cm x 14.17 cm x 16.55 cm) with three feeding slots. Gilts were blocked by weight and randomly assigned within block to treatment pens. After a preliminary week of feeding a standard finisher diet to all trial gilts, to allow for adjustment to the group and surroundings, diets were randomly assigned to treatment pens (two pens/diet). The treatment diets consisted of one of the following levels of DCAD: 50 (control), -225, or -450 mEq/kg diet, and the gilts were fed their respective diet ad libitum for 45 days (Table 1). All diets met or exceeded the nutritional requirements indicated by the NRC (1998). Water intake was not restricted. All diets were corn- and soybean meal-based, and DCAD levels were lowered by the addition of ammonium chloride. Calcium content was kept constant across treatments by the compensatory addition of calcium sulfate. Gilt weights and ultrasound backfat measurements were taken weekly. Feed disappearance was recorded at these times by weighing pen feeders. Room temperatures were maintained between 22 and 29 ºC, and gilts were monitored daily for feed intake, as well as general well-being. Any wet feed was removed daily from the feeder, weighed, and a sample was kept for dry matter analysis. This procedure was repeated in each of the three trials (30 gilts/trial).

During the second and third trial, urine samples were collected weekly from two randomly chosen gilts per pen and immediately analyzed for pH. Gilts were randomly selected each week for urine samples, but during fecal collections, urine samples were collected from the same gilts from which fecal samples were collected. At the beginning and every two weeks throughout each trial, ten mL blood samples were collected by jugular puncture from two randomly selected gilts per pen and immediately analyzed for pH. The two gilts per pen were initially randomly selected, and all subsequent blood sampling was performed on the same gilts. Blood samples were centrifuged and plasma was stored at -20 °C for future analysis.

Chromic oxide was added at 0.25% to all diets offered beginning on day 35 and fecal samples were collected from two gilts in each pen on days 43, 44, and 45. Feces were pooled by pig and stored at -20º C until further analysis. Fecal and feed samples were analyzed for DM, nitrogen (using Leco Nitrogen analyzer, Leco Corp, St. Joseph, MO), and GE (bomb calorimetry, IKA, Wilmington, NC). Chromic oxide content of feed and feces were determined according to the procedure described by Fenton and Fenton (1979). Using the values obtained, DE was calculated from GE based on methods described by Adeola (2001). Dry matter and nitrogen digestibility was similarly calculated.

Statistical analysis: Using the program SPSS (2006), a multivariate analysis of variance with repeated measures was used to analyze for differences over time in weight change, backfat change, and blood pH. In addition, a one-way analysis of variance was run to analyze for differences in ADFI, gain/feed ratio, and urine pH. The experiment design was completely randomized. For all statistical tests, block and trial were used as nested

effects, and treatment was used as the main independent effect. Statistical significance was indicated when $P \leq 0.05$.

Results and Discussion

Average Daily Feed Intake

A one-way analysis of variance indicated overall ADFI was significantly reduced with decreased DCAD treatment (Table 2). However, across week, gilts fed -450 appeared to increase feed intake to reach near levels of control and -225 gilts (Figure 1). These data imply an adaptation to the feed and if the trial would have been extended, ADFI for all treatments may have been statistically similar. The significant effects of replicate and week on ADFI are most likely due to a respiratory challenge during the third week of replicate 3, and the health challenge to all gilts on trial is reflected in consistently lower ADFI across treatments as measured at week 4. A more linear increase of ADFI from -450 treatment in the absence of any health challenges, could be expected, thus allowing the gilts to adapt more quickly to their acidogenic diet.

Table 1. Composition and nutrient analysis of experimental diets

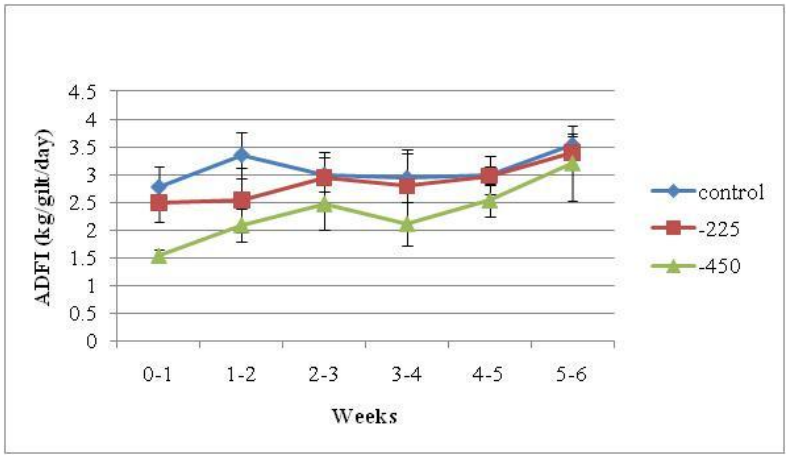
Item	**Diet**		
Ingredients (%)	**Control**	**-225**	**-450**
Corn	79.47	77.25	75.3
Soybean meal	16.64	16.8	16.95
Dicalcium Phosphate	2.15	2.15	2.15
Ammonium Chloride	-	0.965	1.815
Soy Oil	-	0.8	1.55
Calcium Sulfate	-	0.7	1.3
Calcium Carbonate	0.85	0.45	0.05
Salt	0.5	0.5	0.5
Choline Chloride	0.13	0.125	0.125
Trace mineral premix	0.11	0.112	0.112
Base vitamin premix	0.1	0.1	0.1
Sow/Starter vitamin premix	0.05	0.05	0.05
Analyzed nutrient content (%)			
Dry matter	87.36±1.42	86.65±0.87	87.28±0.88
NDF	12.21±1.25	15.0±3.25	15.21±2.48
ADF	2.67±0.29	3.34±0.51	3.65±0.43
Ash	4.64±0.48	5.98±0.32	6.29±0.57
N	1.97±0.30	2.34±0.30	2.97±0.45
CP	12.33±1.90	14.61±1.88[a]	18.57±2.81[a]
Fat	1.67±1.09	2.04±0.74	2.59±0.91
Ca	1.08±0.16	1.23±0.12	1.12±0.14
P	0.54±0.20	0.53±0.06	0.49±0.08
K	0.36±0.14	0.39±0.09	0.48±0.05
Na	0.31±0.20	0.36±0.21	0.37±0.26
S	0.18±0.04	0.46±0.03	0.67±0.03

[a] When the nitrogen provided by the ammonium chloride is taken into account, the CP is similar to control.

Table 2. Effect of DCAD treatment on gilt performance and diet digestibility.

Item	Control	-225	-450	PSEM
ADFI (kg)	3.09[a]	2.86[b]	2.33[c]	0.06
Weight (kg)	143.44[a]	141.69[a]	134.15[b]	17.37
Gain (kg)	4.87[a]	4.60[a]	2.47[b]	0.95
G:F	0.22 [a]	0.23[a]	0.12[b]	0.02
Backfat (mm)	16.94	17.30	15.71	0.72
Urine pH	6.63[a]	5.56[b]	5.81[c]	0.04
Blood pH	7.40	7.32	7.32	0.04
Dry matter digestibility (%)	92.54	92.93	91.74	0.61
Energy digestibility (%)	76.98	76.46	74.35	1.39
Nitrogen digestibility (%)	71.89[a]	75.76[b]	78.32[b]	1.00

[a,b,c]Within a row, means with different subscripts differ, $P \leq 0.05$.



Gilt Performance

Repeated measures analysis of variance indicated a highly significant effect of treatment over time on gilt weight. All weekly measurements of weight differed significantly from measurements taken the previous week (Figure 2). Overall, treatment had a significant effect on BW. The -450 treatment was associated with consistently lower weights ($P < 0.01$) compared to both the -225 and control treatments.

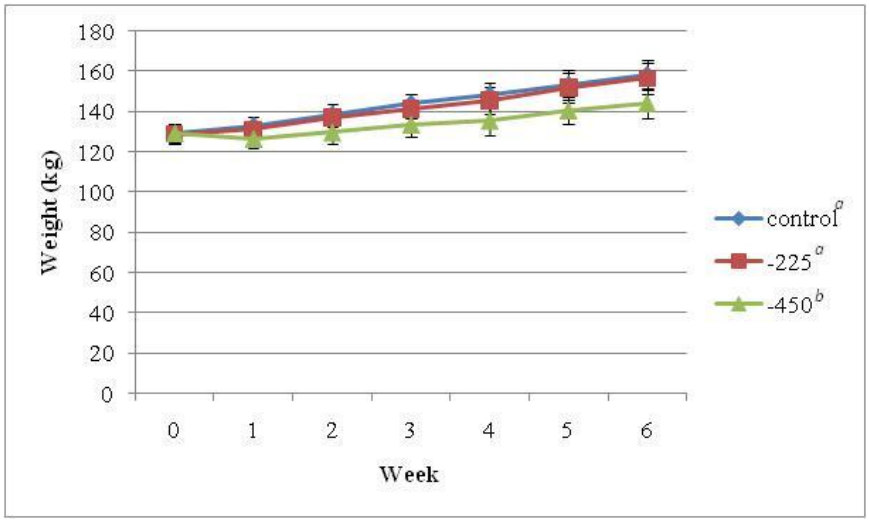


Figure 2. Treatment effect on gilt BW across week.
[ab] Treatments with different superscripts differ significantly $P < 0.05$.

The -225 treatment did not affect BW at all when compared to control, and even though -450 suppressed BW, it did not cause gilts to maintain their initial weight. This is most likely explained by the fact that the gilts used in this study were still growing. Another explanation could be that the level of DCAD was not decreased sufficiently to maintain the original physiological responses observed. This could explain the absence of any effect on BW from
-225 and the lack of literature on intentionally suppressing weight gain with the use of DCAD makes it difficult to draw direct comparisons to other studies.

Similar to the statistical results for BW, treatment significantly affected ADG. Treatment -450 was associated with consistently lower ADG than both the -225 and the control treatment. Treatment -225 had no effect on ADG. The nested effects of block (trial) significantly affected both BW and ADG. The significant differences seen among trials was most likely due to a respiratory outbreak during the third week of trial 3, and the health challenge to all gilts on trial 3 is reflected in consistently lower BW (and lower ADG) across treatments as measured at week 4.

In addition, repeated measures analysis of variance indicated a significant effect of treatment over time on backfat. Specifically, wk 2 compared to wk 1, wk 5 compared to wk 4, and wk 6 compared to wk 5 (Figure 3). Overall, there was a trend ($p=0.084$) for -450 to maintain a lower backfat than both control and -225. Backfat gain was observed in all gilts across all treatments, which may indicate that body stores of backfat are not used to compensate for energy deficiency (Bergsma et al., 2009).

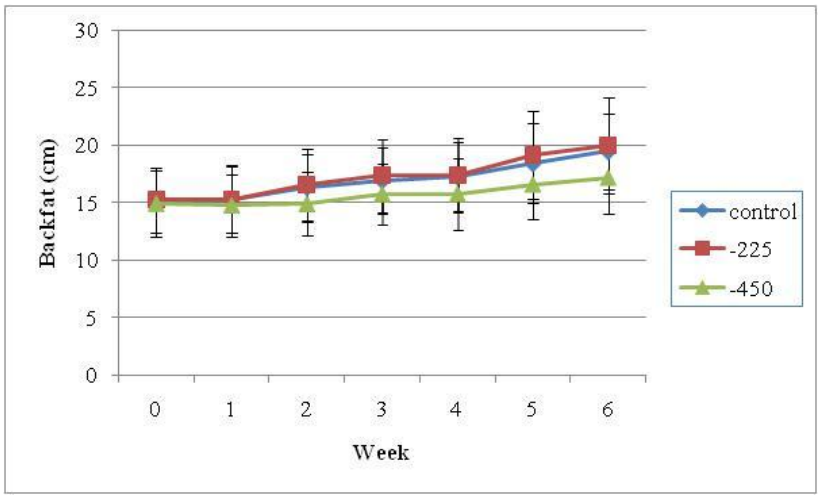


Figure 3. Treatment effect on backfat across week.

Similar to the statistical results for BW and ADG, treatment significantly affected gain/feed. Treatment -450 was associated with consistently lower gain/feed than both -225 and control gilts. Treatment -225 had no effect on gain/feed. This is contrary to previous research that found feed conversion rate improves as DCAD decreases (Arabaci, M., 2010).
The nested effects of block(trial) did not affect gain/feed. These findings are consistent with the nested effects caused by a respiratory outbreak in week 3 of trial 3. The sickness equally affected ADFI and ADG, therefore the ratio between the two (G/F) remained unaffected throughout the trial.
Urine pH

A one-way analysis of variance was used to analyze urine pH, and treatment was found to significantly affect urine pH. Specifically, from week 1 until the end of the trial, both -450 and -225 urine samples were significantly lower in pH than the control diet. The -450 treatment differed from -225 at weeks 2, 5 and 6 (Figure 4). There was no nested effect ($p=0.239$) of block (trial) on urine pH. Although urine samples were not collected from the same pig every week, the data is consistent with previous research (Golz and Crenshaw, 1991; Gelfert et al., 2007; Las et al., 2007; Hersom et al., 2010; Luebbe et al., 2011). The observed average urine pH for -450 and -225 correspond to values reported by Luebbe et al. (2011). In their study, urine pH measured from treatments of -240 and -450 were 5.77 and 5.8, respectively. Therefore, urine pH measurements from this study are in the anticipated range.

The drop in urinary pH for all treatments (even gilts consuming the control diet) from the beginning of the trial to the end of week 1, indicate that all experimental diets may have had a lower DCAD than the finisher diet the gilts were offered prior to the start of the trial. The gilts consuming the control diet were required to physiologically compensate for the added (and unanticipated) acid load, therefore a drop in urine pH was observed. Roux et al. (2008) determined that the DCAD for their control corn and soybean meal diet fed to gestating sows was 140 mEq/kg. If this is an accurate estimation for standard corn and soybean meal diets, then the transition to the experimental control diet (with an anticipated DCAD of 50 mEq/kg) could elicit a slightly acidogenic response.

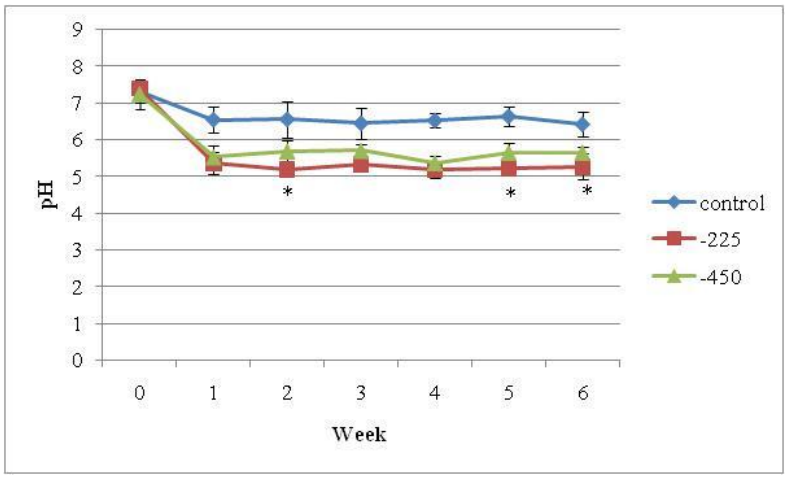


Figure 4. Treatment effect on urine pH across week.
*Indicates weeks where -450 and -225 treatments differed significantly.

Table 3. Pre-trial finisher diet and control diet composition and nutrient content

Item	**Diet**	
Ingredients (%)	**Finisher**	**Control DCAD**
corn	75.95	79.47
soybean meal	21.93	16.64
Nutrient (%)	*Calculated content*	*Analyzed content*
NDF	9.27	12.21
ADF	3.33	2.67
N	2.75	1.97
CP	17.19	12.33
fat	3.65	1.67
Ca	0.45	1.08
P	0.37	0.54
K	*	0.36
Na	0.21	0.31
S	*	0.18

* indicates data not available

Blood pH

Repeated measures analysis of variance indicated that there was no effect (p=0.111) of treatment on blood pH over time, but the nested effect of block(trial) had an effect (p=0.001) on blood pH as measured over time (Figure 5). In particular, the change in blood pH was different between trials 2 and 3 for week 2 as compared to week 0, and for week 4 as compared to week 2. The differences in blood pH response between trials cannot be explained, but may be due to experimental error involving the pH instrument. Across both trials, there was a trend (p=0.089) for DCAD treatment to lower blood pH. If experimental n were higher, we may expect to see a significant decrease in blood pH with decreasing DCAD which would be consistent with previous findings (Patience and Chaplin, 1997; DeRouchey et al., 2003; Las et al., 2007). As described by Mongin (1981), a diet with decreased DCAD subsequently decreases the base excess of the blood (in particular bicarbonate) in order to maintain acid-base homeostasis and lowers blood pH. To enhance the results obtained in this study,

concentration of blood bicarbonate could have been measured. Though this study observed a non-significant trend for DCAD treatment to lower blood pH, measurement of blood bicarbonate may have provided additional clarification of DCAD alteration on blood characteristics.

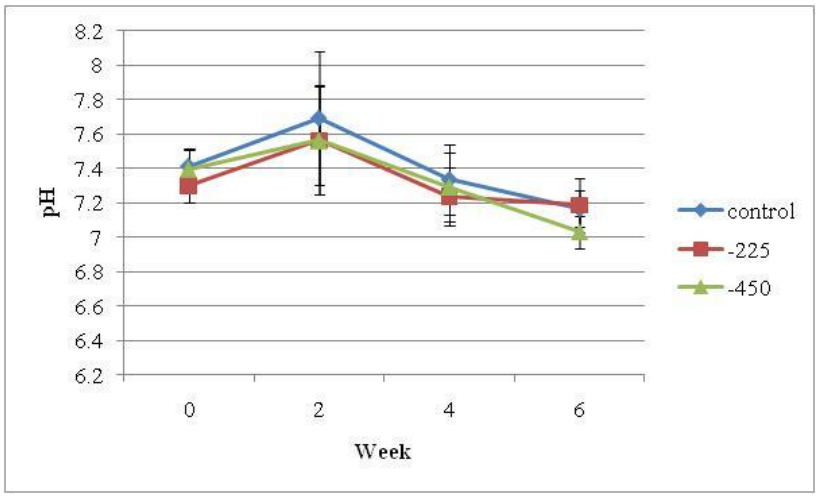


Figure 5. Blood pH averaged per treatment across week.

Nutrient Digestibility

Dry matter and energy digestibility were not affected by treatment. However, decreasing DCAD significantly increased nitrogen digestibility. The data for energy and DM digestibility are consistent with studies conducted by Haydon and West (1990) and Golz and Crenshaw (1991). Unfortunately, the literature regarding digestibility as affected by DCAD does not completely agree. Dersjant-Li et al. (2001a) reported increased fecal dry matter and nitrogen digestibility with increasing DCAD. In a separate study, they suggest that N and energy trends were opposite for the same levels of DCAD, but vary for levels of nonstarch polysaccharide (NSP) composition. Specifically, diets containing higher NSP content and decreased DCAD have increased digestibility of DM, N and energy. Diets with lower NSP content and decreased DCAD have the opposite effect on digestibility i.e. decreased DM, N and energy digestibility (Dersjant-Li et al., 2001b). The NSP content of all diets used in this study correspond to the higher NSP content used in the previously mentioned study (15%); therefore, the increase in nitrogen digestibility with decreasing DCAD is consistent with their findings.

Implications:

Results from this study indicate that the addition of chloride to swine diets may be an effective strategy to decrease feed intake, while maintaining body condition and nutrient digestibility. Altering DCAD may be of particular use in gestating sow diets, when sows are housed in group pens and when a low cost method of feeding is desired. This study observed the effects of added dietary chloride on gilts only, and although no negative side effects on body condition, nutrient digestibility, or skeletal integrity were noted over the course of the six week trial, prolonged induced metabolic acidosis resulting from DCAD may eventually lead to clinically detrimental side effects. Further research is needed in order to determine whether or not similar effects would be observed in gestating sows if fed similar diets over the course of gestation.

A fourth trial is currently in progress. This trial is designed for eight weeks (56 d) but if performance at 56 d is as hypothesized the trial will proceed another 19 d or 75 d total. Seventy-five days is the length of time

gestating sows are in group housing if sows are housed in individual stalls the first 35 d of pregnancy until pregnancy checked and if sows are removed from group housing on d 110 and placed into farrowing stalls. The fourth trial has three treatments: control, -440 DCAD and -225 for two weeks switched to -550 DCAD. The fourth trial is funded by Illinois State University but NPB will be provided the results of Trial 4 upon its completion.

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