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Dietary Manipulation To Reduce Ammonia Concentration in Nursery Pig Facilities

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Summary and Implications

Five trials were conducted to determine the effects of Yucca schidigera *extract or calcium chloride addition to the diet on aerial ammonia concentration and growth performance in nursery pigs. Trials were divided into two groups: preliminary studies (two trials) and major study (three trials). Pigs were fed one of three diets in separate, environmentally regulated rooms: 1) Control, containing 23% CP; 2) Control diet plus 125 ppm of* Yucca schidigera *extract; and 3) Control plus 1.95% calcium chloride. Average daily gain (ADG), average daily feed intake (ADFI), and ADG/ADFI were recorded weekly. Aerial ammonia concentration was measured daily using aspiration detector tubes and during the last week of each trial using diffusion tubes. Blood samples were collected at the end of each trial to determine plasma urea concentration. There were no differences in ADG, ADFI, and ADG/ADFI between pigs fed the control diet and pigs fed the* Yucca schidigera *diet. In all trials, pigs fed the calcium chloride diet had lower ADG and ADG/ADFI than pigs fed the other two diets ($P < .05$). In the preliminary studies (Trials 1 and 2), aerial ammonia concentration tended to be greater in the rooms in which pigs were fed the control diet than in the rooms with pigs fed the yucca extract diet ($P < .08$) or calcium chloride diet ($P < .11$). In the major study (Trials 3, 4, and 5), aerial ammonia concentration increased as the experiment progressed ($P < .001$) in all rooms. In the fourth week, ammonia concentrations were greater ($P < .001$) in the rooms that housed pigs fed the control diet than in the rooms in which the other two diets were fed. Dietary treatment did not affect plasma urea concentration ($P > .10$). This research has shown that ammonia concentration in nursery pig facilities can be reduced by dietary manipulation such as the addition of* Yucca schidigera *extract or calcium salts.*

Introduction

Ammonia is one of the gases of most concern in swine buildings and is a major source of indoor air contamination. The large variation in aerial ammonia concentration is influenced by the bacterial activity and the presence of ideal fermentation conditions. Ammonia volatilization is a process that depends on factors such as concentration of aerial ammonia, air speed in the building, ammonia and dry matter content in the manure, pH of manure, and slurry temperature.

In addition to objectional odors, there also is concern about the health problems that ammonia exposure may produce in animals and animal caretakers. We reported a review of the ammonia issue and pork production in the Nebraska Swine Report (1999) and identified a clear need to continue to evaluate methods to reduce and control odor from livestock enterprises, especially pork production units. These methods include reducing of ammonia concentration using certain additives in growing pig diets such as *Yucca*

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schidigera extract or calcium salts. These additives have been successful in reducing ammonia concentrations in growing pig facilities by 26 and 33%, respectively. By adding calcium salts such as calcium chloride to the diet, the dietary electrolyte balance can be reduced. Dietary mineral balance may be expressed as Na+K-Cl (hereafter referred to as electrolyte balance) which considers the monovalent minerals ions in the diet. Diets with high levels of protein and amino acids that are typical for nursery-age pigs can increase the amount of nitrogen excreted in urine and feces, and this can increase ammonia production. Based on these observations, we designed a study to determine the effect of *Yucca schidigera* extract and calcium chloride addition to nursery diets on aerial ammonia concentration.

Procedures

This research consisted of five trials: two preliminary four-week trials (preliminary study) and three, five-week trials (major study). The objective of the preliminary trials was to establish the ammonia concentration in our environmentally regulated nursery pig facilities. Information about each trial is presented in Table 1. In all trials, pigs were blocked on initial weight and allotted to one of three environmentally controlled rooms such that the average initial weight within each room was similar. In the major study, the three trials, three rooms, and three dietary treatments constituted a Latin square design such that each treatment was assigned in turn to each room.

Pigs were weighed and feed disappearance was recorded weekly to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (ADG/ADFI). During the first week of each trial, all pigs were fed the same standard commercial prestarter diet (23.5% CP, 1.75% lysine, .75% Ca, and .70% P, with apramycin [as apramycin sulfate, 150 g/T]), to allow them to adapt to the initial stress of weaning. For the next three weeks (Trials 1 and 2) and four weeks (Trials 3 to 5), three experimental diets were fed. All diets were formulated to meet or exceed the nutrient requirements of nursery pigs (NRC, 1998). Diets (Table 2) used were 1) Control, 2) Control plus 125 ppm of *Yucca schidigera* extract (De-Odorase, Alltech, Nicholasville, KY), and 3) Control plus 1.95% calcium chloride.

Table 1. Details of the five trials conducted to determine the effects of the addition of *Yucca schidigera* extract or calcium chloride to nursery diets.

Trial	Purpose	Duration wk[a]	Pigs per pen (barrows, gilts)[b]	Weaning age, d	Weaning wt, lb
1	Preliminary	1 + 3	6,0	15	11.4
2	Preliminary	1 + 3	6,4	13	6.6
3	Major	1 + 4	7,3	13	7.7
4	Major	1 + 4	6,4	15	13.0
5	Major	1 + 4	5,5	14	10.5

[a]Each trial consisted of a 1-wk initial period followed by a 3- or 4-wk experimental period.
[b]Each room with five pens, 6.7 ft^2/pig (Trial 1) and 4.03 ft^2/pig (Trials 2, 3, 4, and 5).

Table 2. Composition and analysis of diets[a].

Item	Control	*Yucca schidigera*	Calcium chloride
Ingredient, %			
Corn	30.33	30.32	28.38
Soybean meal (46.5% CP)	20.50	20.50	20.50
Dried whey	30.00	30.00	30.00
Spray-dried plasma protein	6.00	6.00	6.00
Menhaden fishmeal	5.00	5.00	5.00
Corn oil	5.00	5.00	5.00
Dicalcium phosphate	1.55	1.55	1.55
Vitamin premix[b]	1.00	1.00	1.00
Trace mineral premix[c]	.20	.20	.20
Zinc oxide (72% zinc)	.42	.42	.42
Yucca schidigera extract[d]	—	.013	—
Calcium chloride[e]	—	—	1.95
Nutrient composition			
Crude protein[f], %	23.20	23.30	22.90
Lysine[g], %	1.58	1.58	1.58
Ca[f], %	1.13	1.12	1.76
P[f], %	.91	.98	.97
Na + K – Cl, mEq/kg[h]	345	345	-7

[a]As-fed basis.
[b]Supplied per kilogram of diet: retinyl acetate, 4,409 IU; cholecalciferol, 551 IU; all-rac-α-topheryl acetate, 22 IU; menadione (as menadione sodium bisulfite complex), 3.3 mg; riboflavin, 5.6 mg; d-pantothenic acid (as d-calcium pantothenate), 22 mg; niacin, 33 mg; choline (as choline chloride), 110 mg; cyanocobalamin, 22 μg.
[c]Supplied (mg/kg of diet): Cu (as $CuSO_4 \cdot 5H_2O$), 22; I (as $Ca(IO_3)2$), 44; Fe (as $FeSO_4 \cdot H_2O$), 220; Mn (as MnO), 44; Se (as Na_2SeO_3), 0.6; Zn (as ZnO), 220.
[d]*Yucca schidigera* extract (De-Odorase®, Alltech, Nicholasville, KY) added at the rate of 125 ppm (4 oz/ton).
[e]Calcium chloride (36.1% Ca; 63.9% Cl).
[f]Analyzed composition.
[g]Calculated composition.
[h]dEB (dietary electrolyte balance) = Na + K – Cl.

There were three identical pig nursery rooms. Each room had five pens and all pens had plastic-coated wire flooring; one nipple waterer; and one, three-hole, stainless steel feeder. Pigs had *ad libitum* access to feed and water throughout the trial. Heat lamps and comfort boards were provided during the first week after weaning.

In each room, relative humidity (maintained at 60%) and temperature

Table 3. Growth performance, plasma urea concentration and ammonia concentration measured by diffusion tubes of pigs fed either a control diet, a diet with *Yucca schidigera*[a] extract, or calcium chloride diet[b] during the preliminary studies (Trials 1[c] and 2[d]).

Item	Control	*Yucca schidigera*	Calcium chloride	SEM[e]	P-Value[f]
ADG, lb	.765[g]	.765[g]	.565[h]	.019	.027
ADFI, lb	1.111	1.157	1.031	.043	.320
ADG/ADFI	1.511[g]	1.452[g]	1.166[h]	.040	.045
Urea, mg/100 mL	35.68	35.59	29.35	1.200	.100
Aerial ammonia, ppm	8.00	5.60	7.30	2.028	.711

[a]*Yucca schidigera* extract (De-Odorase®, Alltech, Nicholasville, KY) added at the rate of 125 ppm.
[b]1.95% calcium chloride added.
[c]Each room with five pens with six barrows per pen. Initial weight 11.4 lb; final weight 31.2 lb. 28-d experiment; 21-d experimental diets.
[d]Each room with five pens with ten pigs (six barrows and four gilts) per pen. Initial weight 6.6 lb; final weight 20.3 lb. 28-d experiment; 21-d experimental diets.
[e]Standard error of means.
[f]Significance of main effect.
[g,h]Within a row, means without a common superscript letter differ (P < .05).

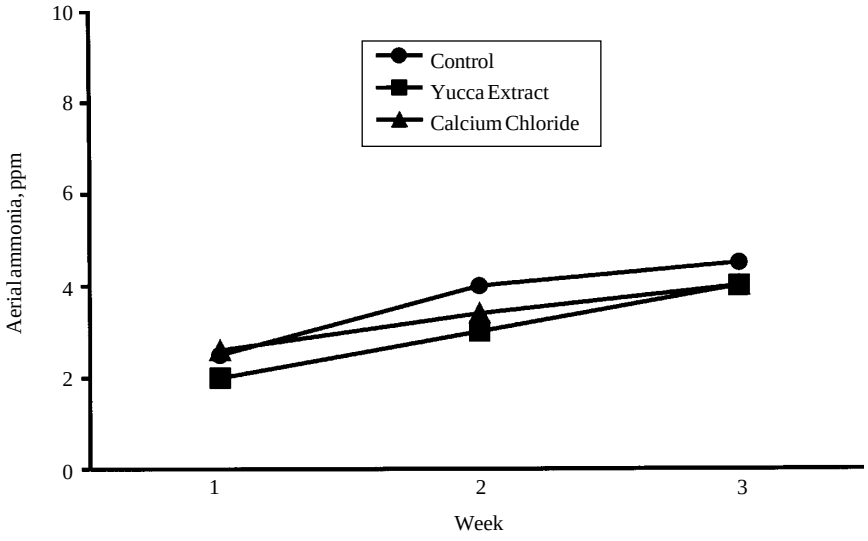

Figure 1. Aerial ammonia concentrations measured by ammonia aspiration tubes (SEM=.16) in rooms with pigs fed a control, *Yucca schidigera* extract (De-Odorase), or calcium chloride diet (preliminary studies).

(maintained at 77°F) were monitored continuously using temperature and humidity recorders. Airflow in the exhaust duct from each room (maintained at 920 ft^3/min) was measured two times per day (8:00 am and 2:00 pm) using an air velocity meter. Aerial ammonia concentration was measured every day at 8:00 am by using Sensidyne aspiration tubes. Air was sampled in the center of the left and right sides of the rooms approximately 3.3 ft above floor level. Ammonia was also measured using 8-hour Dräger diffusion tubes distributed throughout each room at approximately 1.6 ft above the floor three times during the last week of each trial. Five tubes were used per room to measure differences in ammonia concentration in different places in the rooms.

Feces and urine that collected below the pens were allowed to accumulate throughout the trials. Manure (feces, urine, spilled feed and spilled drinking water) that drained from the pens was maintained in a collection pit located at the end of each room. These pits were emptied weekly because their capacity was limited. Water was not added when pits were emptied. Blood was collected from the jugular vein of each pig at the end of the trial to determine plasma urea concentration.

Results

Preliminary Studies: There were no differences in ADG, ADFI, and ADG/ADFI of pigs fed the control diet and the diet containing *Yucca schidigera* extract diet (Table 3). However, there was a reduction in ADG and ADG/ADFI (P < .05) of pigs fed the calcium chloride diet compared with pigs fed the other two diets. There were no differences in ADFI among pigs fed the three diets. There were no differences in plasma urea concentration among treatments (Table 3).

There was no effect of diet on aerial ammonia measured by either Sensidyne aspiration tubes (Figure 1) or Dräger diffusion tubes (Table 3). However, a tendency for increased aerial ammonia was observed in rooms with pigs fed the control diet compared with rooms in which pigs were fed the *Yucca schidigera* extract diet (P = .08) and the calcium chloride diet (P = .10). Aerial ammonia concentration increased as the experiment progressed (P < .001) in all rooms.

Major Study: There were no differences in ADG, ADFI, and ADG/ADFI of pigs fed the control diet and the pigs fed the diet containing *Yucca schidigera* extract (Table 4). There were no differences in ADFI among pigs fed any of the three diets. There was a significant reduction in ADG and ADG/ADFI (P < .05) of pigs fed the calcium chloride diet compared with pigs fed the other two diets. There were no differences in plasma urea concentration among treatments.

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There was no effect of diet on aerial ammonia measured by Dräger diffusion tubes during the final week of the experiment (Table 4). The aerial ammonia concentrations measured by Sensidyne aspiration tubes increased weekly (P < .001) in all treatments (Figure 2). There was a diet x week (P < .001) interaction, with a greater increase of aerial ammonia in rooms with pigs fed the control diet compared with the other rooms. Differences among treatments were evident during the third week (P = .07) and clear during the fourth week (P < .001), when ammonia concentration was 2.5 and 2.7 ppm higher in rooms with pigs fed the control diet compared with the concentration in rooms with pigs fed the yucca extract and the calcium chloride diets, respectively (Figure 2).

Table 4. Growth performance, plasma urea concentration and ammonia concentration measured by diffusion tubes of pigs fed either a control diet, a diet with *Yucca schidigera*[a] extract, or calcium chloride diet[b] during the major study (Trials 3[c], 4[d], and 5[e]).

Item	Control	*Yucca schidigera*	Calcium chloride	SEM[f]	P-Value[g]
ADG, lb	.968[h]	.965[h]	.732[i]	.023	.028
ADFI, lb	1.364	1.339	1.229	.073	.456
ADG/ADFI	1.579[h]	1.621[h]	1.291[i]	.041	.050
Urea, mg/100 mL	29.29	27.73	26.48	1.170	.400
Aerial ammonia, ppm	8.92	8.28	5.75	1.220	.348

[a] *Yucca schidigera* extract (De-Odorase®, Alltech, Nicholasville, KY) added at the rate of 125 ppm (4 oz/ton).
[b] 1.95% calcium chloride added.
[c] Each room with five pens with ten pigs (seven barrows and three gilts) per pen. Initial weight 7.7 lb; final weight 33.44 lb, 35-d experiment; 28-d experimental diets.
[d] Each room with five pens with ten pigs (six barrows and four gilts) per pen. Initial weight 13.0 lb; final weight 41.5 lb; 35-d experiment; 28-d experimental diets.
[e] Each room with five pens with ten pigs (five barrows and five gilts) per pen. Initial weight 10.5 lb; final weight 38.4 lb; 35-d experiment; 28-d experimental diets.
[f] Standard error of means.
[g] Significance of main effects.
[h,i] Within a row, means without a common superscript letter differ (P < 0.05).

Discussion

In this experiment, there was no effect of yucca extract additive on growth performance in nursery pigs. Lowering the dietary electrolyte balance with calcium chloride resulted in reduced ADG and ADG/ADFI compared with pigs fed the control or yucca extract diets. This was probably due to a metabolic acidosis produced by the increased plasma chloride, which is the mechanism by which calcium chloride generally decreases feed intake and weight gain. In this research, feed intake was reduced by 7% to 10% in pigs fed the calcium chloride versus the control diet in the preliminary studies, but this difference was not statistically significant.

Ammonia concentrations were relatively low, probably because of the small size of the pigs and the high ventilation rate in our research facility. The lower weight gain in pigs fed the calcium chloride diet may have been at least partly responsible for the decreased ammonia concentration in rooms in which pigs were fed this treatment.

Ammonia concentration measured by diffusion tubes was not different among the three rooms. However, lower concentrations were measured by aspiration tubes in rooms with pigs fed yucca extract or calcium chloride compared with the control diet. There was considerable variation in ammonia concentration among samples obtained from different locations in the rooms. Ammonia concentrations were highest when the tubes were placed over the manure maintained below the pens. Lower concentrations of ammonia were measured when samples were taken from the right side of the room (few feces on the floor) compared with the left side (feces on the floor) or when measured over the collection pit.

In this study, manure collection pits were emptied weekly because the

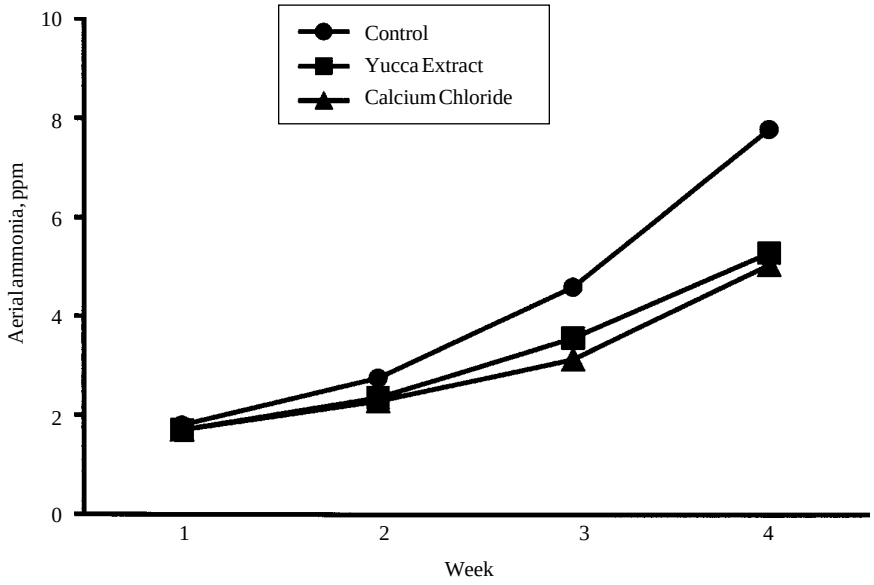

Figure 2. Aerial ammonia concentrations measured by ammonia aspiration tubes (SEM=.54) in rooms with pigs fed a control, *Yucca schidigera* extract (De-Odorase), or calcium chloride diet (major study).

capacity to store feces, urine, waste feed and spilled drinking water was limited. This may have limited aerial ammonia concentration. In spite of the relatively low concentration of aerial ammonia, these results show that *Yucca schidigera* extract and calcium chloride diets can be used to reduce ammonia concentration from nursery pig facilities. These effects were most evident during the third and fourth weeks of the major study.

Plasma urea concentration was not affected by diet. In the present study, crude protein levels and ADFI were similar among treatments. Apparently the changes in ammonia concentration caused by the dietary treatments were not reflected in changes in plasma urea.

Conclusions

The results from these studies indicate that ammonia concentrations in nursery pig facilities can be reduced by using feed additives such as *Yucca schidigera* extract and calcium chloride. Aerial ammonia concentrations increased steadily as the trials progressed, but never reached excessive concentrations. However, under commercial conditions, where the air exchange rate is lower and the density of nursery pigs is greater than those used in this study, aerial ammonia concentrations may be higher. The different response of growth performance between pigs fed the calcium chloride diet and the pigs fed the control diet can be attributed to alterations in the dietary electrolyte balance in pigs fed calcium chloride. Further research is needed to determine the optimal concentration of this calcium salt that must be added to nursery diets to reduce ammonia concentration without reducing growth performance.

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