Title: Quantification of gas and odor emissions from swine wean-finish facilities
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Abstract

A total of 960 pigs (equal barrows and gilts) were used in a 2 x 2 factorial, wean to finish experiment to determine the effects of diet (control, CTL vs. low nutrient excretion, LNE) and manure pit management strategy (deep pit, DP vs. monthly pull plug, PP) on excretion of nutrients and gaseous and particulate emissions. Pigs were housed in a 12 room environmental building, which allows for real-time monitoring of air quality, and quantitative manure collection from 24 pits (2/room). Each room contained 30 barrows (3 pens) and 30 gilts (3 pens), which were split-sex and phase-fed to meet or exceed the nutrient requirements of pigs (NRC, 1998) at different stages of growth. Dietary treatments (CTL and LNE) were maintained throughout the trial. Individual pig weights and pen feed consumption data were collected every two weeks. Four pigs from each pen were scanned ultrasonically for determination of loin eye area and backfat thickness at two months of age and every four weeks thereafter during the study. At the end of the experiment, carcass data was collected at harvest on all pigs. Ammonia, hydrogen sulfide, carbon dioxide, methane, and sulfur dioxide concentrations were recorded every fourth week during the experiment. In addition, odor samples were collected at months 1, 3 and 5 of each wean-finish replicate in this experiment. A dynamic dilution venturi olfactometer was used, with trained panelists, to evaluate air samples for olfactometry.

Throughout most phases of the trial, pigs fed the LNE diet grew faster ($P<0.002$) than CTL fed pigs while consuming less feed, resulting in an improved feed efficiency. Manure pit management strategy had no effect on animal performance, except feed efficiency tended ($P<0.07$) to be improved when pigs were housed in rooms with monthly removal of manure compared to manure accumulated in a deep pit for the entire wean-finish period. Carcass backfat depth was increased ($P<0.001$); % lean was decreased ($P<0.001$) and hot carcass weight was increased ($P<0.003$) in pigs fed the LNE diet compared to the CTL diet. Market weight ultrasound loin eye area was

increased ($P<0.004$) in pigs fed the LNE diet compared to the CTL diet. Aerial ammonia concentrations were reduced 14% by feeding the LNE diet ($P<0.001$) and were reduced 6% by removing manure from pits monthly ($P<0.005$). Methane concentrations were reduced 18% with the monthly manure removal strategy ($P<0.001$) compared to deep pit accumulation. Ammonia, hydrogen sulfide, carbon dioxide and methane concentrations varied with different stages of pig growth. Olfactometry measures of odor detection threshold and intensity were not affected by diet or manure management strategies.

Introduction

In the past two decades, the pork industry has undergone a rapid rate of technological and structural change. The most significant changes have been a decrease in farm numbers, an increase in farm size and the movement of large production operations to more remote areas of the country. New regulatory pressures to meet water and air quality standards for CAFO's (EPA, 2003) and NPDES permit regulations, the possibility of having to meet total maximum daily load (TMDL) of contaminants in the water supply and strict air quality regulations are placing additional economic and management burdens on pork producers that may lead to further loss of production units and consolidation of the industry.

Media attention and activist groups have been applying pressure on producers, legislators and regulators for changes in oversight of livestock operations. In many cases, odors, dust and gas emissions from swine units have resulted in nuisance lawsuits and unrealistic regulations not necessarily based on scientific evidence. Residents near operations are concerned about the potential devaluation of their property and the impact of manure and odors on their health and lifestyle. State and local governments are struggling to develop long term land use plans to maintain sufficient land areas for both pork operations with land application of manure and the influx of urban residents into rural areas.

Several states are attempting to develop or enforce air quality regulations. However the focus of these regulations is variable ranging from NH_3 or H_2S emissions, to dust particulate emissions, or odor measurements from buildings, lagoons, or open feedlots, at specific distances from the entire production facility. Variable distances to the swine operation property line or to the next adjoining neighbor, and variable atmospheric conditions including wind speed, direction, humidity, season, temperature, etc, make it nearly impossible to ascertain realistic air pollution emission data values and to set a standard that is dependable. It is difficult to define a standard sampling and measurement procedure and a regulatory standard for livestock emissions. Even with more concentrated emissions from enclosed confinement buildings, there is considerable variation in air pollutant emissions evident at different seasons of the year, temperatures, and animal activity. In fact, the diurnal flux of emissions within a 24-hr period creates variability with different sampling times and procedures. Reliable and scientifically controlled research for data on emission rates, flux rates, and emission factors are needed to develop science-based policies for the reduction of animal feeding operation odor, gas and dust emissions.

Unfortunately, animal feeding operations can affect air quality through emissions of odor, odorous gases (odorants), particulates (including biologic particulate matter), volatile organic compounds, and some greenhouse gases (Arogo et al., 2001; Bicudo, et al., 2001; Sweeten, et al., 2001; USDA AAQTF, 2001; and NAS, 2003). Much of the emitted gases come from anaerobic decomposition of manure during storage, the release of volatile organic compounds and ammonia immediately after excretion from the animal and dust generated in the building from feed delivery systems, animal movement, and hair and sloughed skin from the animal. It has been predicted that gas emissions and odors from animal feeding sources can be a composite from as many as 160 to over 400 specific compounds. They have been generally grouped as volatile amines, sulfides, organic acids, phenols, alcohols, carbonyls, nitrogen heterocycles, esters, and mercaptans. The primary gases of concern that are specifically identified in the Clean Air Act include ammonia (NH_3), hydrogen sulfide (H_2S), methane (CH_4), and nitrous oxides (NO_X). In addition, particulate matter identified as PM_{10} and $PM_{2.5}$ has been targeted as an atmospheric pollutant because of its deleterious impact on the respiratory system of humans (Auvermann, et al., 2001; Schiffman, et al., 2001).

Several methods have been used to control odor emissions from manure in pork production. However, there has been very little research documenting the effects of diet modification and different manure management strategies on odors and gas emissions in controlled, high quality test facilities where results would translate to commercial housing situations. This information is critical if we are to transfer new research technology to pork producers for implementation. Therefore the objectives of this trial were to determine the amount of gases and odors emitted from buildings when swine were fed a control or a low nutrient excretion diet and manure was managed as a deep pit or a monthly pull plug system.

Objectives

1) Establish baseline gas and odor emissions from group-fed pigs housed in environmentally controlled facilities at different stages of growth.
2) Conduct a nutrition study to determine the value of diets formulated with non-sulfur trace minerals, phytase, and protein and amino acid manipulation, and their effects on excretion of odorous compounds or precursors of odorous compounds in manure and gas emissions in group-fed pig housing facilities.
3) Determine the effect of manure storage time (1 or 6 months) within a housing facility on gas and odor emissions from group-fed pigs.

Materials and Methods

Animal design

Nine hundred and sixty (avg initial BW = 5.16 kg; avg final BW = 128.16 kg) wean-finish pigs (PIC 280 x C22) were utilized. Pigs were housed in an environmentally controlled building with identical and independent ventilation, feeding systems, water, and manure storage pits. Each room housed 10 pigs per pen with 60 pigs per room. Pigs were blocked by BW and sex and randomly allotted to 1 of 4 treatments arranged in a 2 X 2 factorial design with 2 diet formulations (standard commercial corn-SBM control, CTL; or a low nutrient excretion diet, LNE) and 2 manure storage strategies (6 month deep pit collection, DP; or a monthly pull plug/recharge collection, PP). Pigs were split-sex and phase-fed to meet or exceed nutrient requirements (NRC, 1998). Five nursery phases and four grow-finish phases were fed. Nursery phases included: 1) Pellets, d 0-7; 2) Phase 1, d 7-14; 3) Phase 2, d 14-28; 4) Phase 3, d 28-42; and 5) Phase 4, d 42-56. Grow-finish phases included: 1) Grower 1, d 56-84; 2) Grower 2, d 84-112; 3) Finisher

1, d 112-140; and 4) Finisher 2, d 140-152. Individual pig weights and pen feed consumption data were collected once a week during the nursery pellet phase and phase 1, then every two weeks thereafter. Four pigs from each pen were scanned ultrasonically for determination of loin eye area and 10^{th} rib backfat thickness starting at two months of age and every four weeks thereafter during the study. At the end of the experiment, carcass data were collected at harvest on all pigs by a commercial slaughter facility.

Dietary treatments

Pigs were fed either a commercial corn-soybean meal control (CTL) diet or a low nutrient excretion (LNE) diet (finisher 1 diet shown in Table 1 as an example). The LNE diets had a reduced crude protein level compared to the CTL diets, and included synthetic amino acids, phytase (Natuphos, BASF, New Jersey, USA), added fat, and a non-sulfur trace mineral premix. Diets were formulated based on NRC (1998) requirements for available phosphorus and true ileal digestible amino acids (PIC recommendations), while maintaining similar TID lysine:calorie ratios.

Gas concentration monitoring

Continuous real-time instruments monitored ammonia (NH_3), hydrogen sulfide (H_2S), carbon dioxide (CO_2), and methane (CH_4) every fourth week during the trial. Real-time monitoring was conducted for 5 days during the fourth week before sampling manure from the pit, during pit sampling and emptying (PP system) and for 2 days after pit sampling.

Thirty nine odor samples were collected at months 1, 3, and 5 of each replicate with three samples obtained from each room exhaust and three from the fresh air plenum that is common to all rooms. The odor samples were obtained from each room in a weight block of the 2 X 2 arrangement of the treatments simultaneously. Air samples were collected into 10 L Tedlar bags. A dynamic dilution venturi olfactometer (AC'SCENT Internations, St. Croix Sensory, Inc., St. Paul, MN) was used to evaluate each bag sample of air for olfactometry. All evaluations were performed by trained human panelists. Sample evaluation occurred the same day as sampling to minimize bag losses.

Statistical design

All data were analyzed using the GLM procedure of SAS (2006; SAS Institute Inc., Cary, NC). Pen was the experimental unit for animal performance and carcass characteristics; data represents 24 observations per diet and sex treatment combinations. Manure pit was the experimental unit for manure storage strategy and data represents 32 total observations. Finally, room was the experimental unit for aerial gaseous compound concentrations; data represents 16 total room observations, 4 per diet and manure storage combination. Animal performance and carcass characteristics were analyzed for the main effects of dietary treatment, manure storage type, and sex. Gaseous emissions were analyzed for the main effects of dietary treatment, manure storage type, and week of production.

Results

Pig performance

Growth performance was not affected by the LNE diet compared to the control diet throughout the nursery phase except pigs fed the LNE diet consumed less (P<0.003) feed than pigs fed the CTL diet (Table 2). At the end of the nursery phase (d 56), the LNE fed pigs tending to be heavier than CTL fed pigs (35.53 vs. 34.58 kg; P<0.06). The LNE diet decreased ADFI by 5.3% and increased feed efficiency by 9.6%.

Manure storage type did not have any affect on growth performance throughout the study (Table 2). However, removing the manure monthly tended (P<0.07) improve feed efficiency in pigs compared to accumulation in the deep pit for the entire wean-finish feeding trial. The LNE diet fed to pigs increased (P<0.002) ADG by 3.8%, reduced (P<0.002) ADFI by 6.3% and improved (P<0.001) feed efficiency by 10.3% compared to pigs fed the CTL diet during the grow-finish period. Live weights of the LNE pigs were greater (P<0.001) at the end of the trial compared to the CTL pigs (130.6 kg versus 125.7 kg). Barrows grew faster than gilts (P<0.001) and were heavier at harvest (P<0.04). Gilts tended (P<0.06) to consume less feed than barrows. Feed efficiency was the same for barrows and gilts in this study.

Carcass characteristics

Live animal ultrasonic measures of loin eye area were not affected by sex (Table 3). However, backfat depth was higher (P<0.001) in barrows compared to gilts. Pigs fed LNE diets had larger (P<0.004) loin eye areas and increased backfat (P<0.001) compared to CTL fed pigs.

Similar to live ultrasonic measures, carcass backfat thickness, lean percent, carcass grade premium, and hot carcass weight were all affected by dietary treatment (Table 3). Carcass backfat thickness was 8.6% greater (P<0.001) in LNE fed pigs compared to CTL fed pigs. Pigs fed LNE diets also had a decreased lean percentage compared to CTL fed pigs (53.24 vs. 53.80%; P<0.001). Although the live ultrasonic measurements indicated a larger loin eye area for LNE fed pigs, carcass loin depth measurements were not different among dietary treatments. Overall carcass value was not different for LNE and CTL fed pigs. Pigs housed in the DP manure management rooms had increased carcass yield compared to those housed under the monthly manure PP system (P<0.02).

Barrows had 16.3% more backfat (P<0.001) and a heavier hot carcass wt (P<0.002) compared to gilts, which were leaner than barrows (54.06 vs. 52.98%; P<0.001). Total carcass value and live value for gilts were increased (P<0.05) by 2.9, and 2.9%, respectively compared to barrows.

Gas concentrations

Gas concentration data collected from May 2005 to January 2006 reveals that diet, manure storage type, and week of production have significant effects on the concentration of various gaseous compounds (Table 4 and 5). The LNE diets reduced aerial NH_3 concentration over the wean-finish period by 13.6% (P<0.001) compared to CTL diets. The PP system significantly reduced aerial NH_3 concentrations by 7.3% (P<0.005) compared to the DP system. The PP system also reduced aerial CH_4 concentration by 17.7% (9.44 vs. 11.47 ppb; P<0.001) compared to the DP system.

Aerial H_2S and SO_2 concentration were not different ($P>0.10$) among dietary treatments even though LNE diets were formulated with a non-sulfur trace mineral premix. Additionally there was no effect of manure management system on H_2S concentration (139.38 vs. 138.76, respectively; $P>0.10$). However, the PP system tended to increase aerial SO_2 concentration compared to the DP system (12.71 vs. 9.90 ppb, respectively; $P<0.07$).

Air concentration data were also affected by wk of production, except for aerial SO_2 (Table 7). Aerial NH_3, H_2S, and CH_4 concentrations were increased by 43.4, 68.3, and 29.0%, respectively from wk 4 to 16 ($P<0.001$). Conversely, the concentration of CO_2 was reduced by 13.6% during wk 20 compared to wk 4 ($P<0.001$)

Olfactometry (odor) measurements

Even though the composition of the air was changed, there was no significant effect of diet on olfactometry measurements (Table 6). However, the detection threshold tended ($P < 0.10$) to be higher for odors from room air where manure was removed monthly compared to rooms where manure accumulated in the deep pit system. Odor intensity tended to be reduced ($P<0.07$) as pigs grew (Table 7). This was due to an increased air exchange rate with the larger pigs compared to nursery pigs.

Discussion

Feeding the LNE diet supported gains and feed efficiency of pigs compared to a conventional CTL diet. This supports previous research studies. When pigs were fed LNE diets, they consumed less feed, but with similar or, in some cases, increased gains, resulting in more efficient utilization of feed. Carcass evaluations supported earlier studies that with the feeding of LNE diets there is an increase in back fat deposition. Fat was added to the LNE diets which could have contributed to increased fat back fat deposition or with the substitution of corn for reduced soy protein in the diet when synthetic amino acids were included in the diet may have increased the energy level of the diet and contribute to increased back fat deposition. However, these data have not been adjusted for the heavier body weights of the pigs fed LNE diets and on an equal BW basis there may not be as great of an effect on carcass composition. However, in this study, loin eye area was increased in the LNE pigs compared to the CTL pigs. As expected, gilts had lower back fat depth, higher percent lean, higher carcass grade premium, but lower total carcass weight. Treatments did not affect total carcass value in this study.

Ammonia concentrations in the air were reduced by both the feeding of LNE diets to pigs and the removal of manure from a pit monthly. Formulating an LNE diet by reducing soy protein and using synthetic amino acids to closely meet the pig's amino acid requirements significantly reduces the excretion of urea nitrogen in the urine resulting in less ammonia emissions. In addition, less nitrogen excretion reduces the pH of manure which reduces ammonia emission.

Ammonia and methane concentrations in the air were reduced by removing manure on a monthly basis compared to accumulating manure in the pit over the entire feeding period. This affect was due to a reduced time for anaerobic decomposition and release of ammonia and methane and a reduced volume of manure. In addition, approximately 2 inches of fresh water was placed in the pit after removal of the manure which would dilute manure deposited in the pit during the month, thus the concentration of the manure organic matter for degradation and gaseous emissions was considerably less than for more concentrated manure in the deep pit. Hydrogen sulfide concentrations were not affected by treatment, which was surprising because of reduced sulfur in the trace mineral premix in the LNE diets. Potentially there were not enough data points taken in this study to show any statistical differences due to dietary effects on hydrogen sulfide. However, hydrogen sulfide was emitted during manure monthly removal process. The concentrations of ammonia, hydrogen sulfide, and methane increased as the age of pigs increased. This was probably due to the increase in manure production and the longer-term storage of manure as pigs grew.

It is surprising that there were not greater differences in odor measurements with air sampled in this experiment due to treatment. However, the concentration of certain VOCs may have masked reductions observed, resulting in no differences detected by the odor panel. More dramatic changes in diet composition or more frequent removal of manure may be needed to change odor emissions significantly. The intensities of odors from air collected in grower and finisher rooms were reduced due to increased air exchange rates (grower-finisher versus nursery).

Lay Interpretation

The most significant change seen in the swine industry has occurred over the last sixty years. We have seen a shift from many farms producing a limited number of pigs to a small number of large confinement production facilities. New regulatory pressures to meet water and air quality standards for CAFO's and NPDES permit regulations are placing additional economic and management burdens on pork producers, which may lead to further consolidation of the swine industry. Data from this research demonstrates that pigs can be fed low nutrient excretion diets to reduced nutrient excretion and gas concentrations, while maintaining animal performance and carcass characteristics. Pigs fed low nutrient excretion diets had improvements in average daily gain, feed efficiency, and were approximately 5.0 kg heavier at market than pigs fed control diets. Although backfat thickness was greater for low nutrient excretion fed pigs, there was no difference in percent carcass yield or total carcass value. Reducing ammonia by both diet and monthly removal of manure from swine facilities can result in less neighbor concerns,
more acceptance of the swine industry and provides air quality stewardship practices for the pork industry.

References

Arogo, J., P. W. Westerman, A. J. Heber, W. P. Robarge, and J. J. Classen. 2001. Ammonia emissions from animal feeding operations. National center for manure and animal waste management. White Paper, 63 pgs.

Auvermann, B., R. Bottcher, A. Heber, D. Meyer, C. B. Parnell, B. Shaw and J. Worley. 2001. Particulate Matter Emissions from Confined Animal Feeding Operations: Management and Control Measures. National Center for Manure and Animal Waste Management White Paper. 40 pgs.

Bicudo, J. R., R. Gates, L. D. Jacobson, D. R. Schmidt, D. Bundy, and S. Hoff. 2001. Air quality and emissions from livestock and poultry production/waste management systems. National center for manure and animal waste management. White Paper, 56 pgs.

EPA. 2003. National pollutant discharge elimination system permit regulation and effluent limitations guidelines and standards for concentrated animal feeding operations (CAFOs); Final Rule. Federal Register 40 CFR Parts 122 and 412. Vol. 68, No. 29:7175-7274.

NRC. 1998. Nutrient requirements of swine (10th addition). National Academy Press, Washington, DC.

NAS. 2003. The scientific basis of estimating air emissions from animal feeding operations: final report. National Academy of Science. National Academy Press, Washington, DC.

SAS. 2006. SAS User's Guide: Statistics. SAS Institute. Inc., Cary, NC.

Schiffman, S. S., B. W. Auvermann and R. W. Bottcher. 2001. Health Effects of Aerial Emissions from Animal Production and Waste Management Systems. National Center for Manure and Animal Waste Management White Paper. 44 pgs.

Sweeten, J. M., L. D. Jacobson, A. J. Heber, D. R. Schmidt, J. C. Lorimor, P. W. Westerman, J. R. Miner, R. H. Zhang, C. M. Williams, and B. W. Auvermann. 2001. Odor mitigation for concentrated animal feeding operations. National center for manure and animal waste management. White Paper, 54 pgs.

USDA AAQTF. 2001. Air quality research and technology transfer white paper and recommendations for concentrated animal feeding operations. Confined Livestock Air Quality Committee of USDA Agriculture Air Quality Task Force. J. M. Sweeten, Chair.

Table 1. Example Diets: Treatments for Finisher 1.

	Control		LNE	
Ingredients, %	Barrows	Gilts	Barrows	Gilts
Corn	81.05	79.27	81.66	79.68
Soybean meal	17.00	18.79	12.03	14.01
Choice white grease	------	------	4.00	4.00
Calcium carbonate	0.66	0.65	0.90	0.90
Dicalcium phosphate	0.70	0.69	0.34	0.33
Vitamin premix	0.10	0.10	0.10	0.10
TM preminx	0.05	0.05	------	------
Non-sulfur TM premix	------	------	0.05	0.05
Phytase	------	------	0.083	0.083
Salt	0.25	0.25	0.25	0.25
Lysine-HCl	0.10	0.10	0.32	0.32
DL-methionine	------	------	0.05	0.06
L-threonine	0.01	0.02	0.12	0.12
L-tryptophan	------	------	0.02	0.02
Tylan 40	0.025	0.025	0.025	0.025
Se 600	0.05	0.05	0.05	0.05
Calculated Analysis				
ME, kcal/kg	3347	3346	3517	3517
CP, %	14.9	15.6	12.8	13.6
TID Lysine:calorie ratio	2.101	2.235	2.101	2.235
True Ileal Dig. Lys, %	0.70	0.75	0.74	0.79
Calcium, %	0.50	0.50	0.50	0.50
Avail. Phosphorus. %	0.19	0.19	0.19	0.19

Table 2. Effects of diet, manure storage type, and sex on nursery and grow-finishing pig performance.

	Diet		Storage		Sex			P Values		
Main Effects	Control	LNE	Deep Pit	Pull Plug	Barrows	Gilts	MSE	Diet	Storage	Sex
Initial wt, kg	5.15	5.17	5.15	5.16	5.22	5.10	0.800	0.94	0.95	0.46
d 7 wt, kg	6.11	6.12	6.11	6.11	6.16	6.06	0.758	0.98	0.99	0.50
Nursery overall (d 0 to d 56)										
ADG, kg/d	0.45	0.47	0.46	0.46	0.46	0.46	0.133	0.58	0.98	0.82
ADFI, kg/d	0.95	0.90	0.92	0.93	0.92	0.93	0.081	0.003	0.44	0.39
Gain:Feed	0.47	0.52	0.49	0.50	0.49	0.50	0.141	0.13	0.98	0.85
d 56 wt, kg	34.58	35.53	35.02	35.08	34.99	35.11	2.416	0.06	0.90	0.82
Grow-finishing overall (d 56 to d 152)										
ADG, kg/d	0.936	0.972	0.951	0.958	0.975	0.934	0.053	0.002	0.50	0.001
ADFI, kg/d	2.69	2.52	2.64	2.58	2.66	2.56	0.229	0.002	0.26	0.06
Gain:Feed	0.349	0.385	0.362	0.372	0.367	0.367	0.024	0.001	0.07	0.98
d 152 wt, kg[b]	125.68	130.64	128.44	127.88	129.73	126.59	6.237	0.001	0.71	0.04

Table 3. Effects of diet, manure storage type, and sex on ultrasound backfat and loin eye area of grow-finish pigs and carcass characteristics of finishing pigs.

	Diet		Storage		Sex			P Values		
Main Effects	Control	LNE	Deep Pit	Pull Plug	Barrows	Gilts	MSE	Diet	Storage	Sex
Ultrasound data										
Market, d 152[b]										
Loin eye area, cm^2	39.04	40.79	40.36	39.47	39.58	40.25	2.497	0.004	0.45	0.26
Backfat, mm	18.06	20.95	19.59	19.41	21.49	17.51	2.843	0.001	0.79	0.001
Carcass data										
Backfat depth, mm	21.66	23.69	22.57	22.78	24.69	20.66	2.308	0.001	0.66	0.001
Loin depth, cm	6.55	6.52	6.57	6.50	6.51	6.56	0.242	0.57	0.16	0.32
Lean, %	53.80	53.24	53.61	53.43	52.98	54.06	0.629	0.001	0.18	0.001
Hot carcass wt, kg	93.13	96.72	95.13	94.72	96.40	93.45	4.612	0.003	0.66	0.002
Live value, $/kg	1.03	1.01	1.02	1.01	1.00	1.03	0.083	0.16	0.47	0.05
Yield, %	74.00	74.31	74.61	73.69	73.97	74.34	1.833	0.41	0.02	0.32
Total carcass value, $[b]	129.03	130.36	130.24	129.15	129.54	129.86	9.855	0.51	0.59	0.87

Table 4. Effects of diet and manure storage type on air concentration data in a wean-finish confinement building.

Gas concentrations	Diet		Storage		MSE	P Values	
	Control	LNE	Deep Pit	Pull Plug		Diet	Storage
NH_4, ppm	6.6	5.7	6.4	6.0	3.52	0.001	0.005
H_2S, ppb	136.1	142.1	139.4	138.8	286.63	0.65	0.96
SO_2, ppb	11.1	11.5	9.9	12.7	32.89	0.81	0.07
CO_2, ppm	1308.3	1312.5	1318.0	1302.8	353.87	0.86	0.33
CH_4, ppb	10.5	10.4	11.5	9.4	6.37	0.83	0.001

Table 5. Effect of week of production on air concentration data in a wean-finish confinement building[a].

Dietary phase:	Nursery	Grower 1	Grower 2	Finisher 1	Finisher 2		P Values
Week of production:	4	8	12	16	20	MSE	Wk of Production
Gas concentrations							
NH_4, ppm	3.4	6.6	8.6	6.1	6.3	3.52	0.001
H_2S, ppb	56.9	171.2	143.9	179.9	149.5	286.63	0.001
SO_2, ppb	9.9	14.1	13.3	11.2	8.3	32.89	0.24
CO_2, ppm	1424.7	1311.5	1393.7	1157.5	1231.5	353.87	0.001
CH_4, ppb	7.2	11.4	13.0	10.2	10.7	6.37	0.001

Table 6. Effect of diet and manure storage on human olfactometry readings from air collected from a wean-finish confinement building.

Olfactometry	Diet		Storage		MSE	P Values	
	Control	LNE	Deep Pit	Pull Plug		Diet	Storage
Detection threshold, OU/m^3	1382.91	1370.79	1308.06	1445.51	742.607	0.83	0.21
OC, oue/m^3[a]	1340.15	1324.60	1279.98	1384.60	674.945	0.81	0.29
Intensity, full strength	2.83	2.82	2.82	2.82	0.391	0.85	0.82
Hedonic tone, full strength	-4.02	-4.06	-3.99	-4.09	1.149	0.80	0.59
True detection threshold[b]	1211.77	1214.20	1168.99	1257.01	683.015	0.95	0.40
True OUE[b]	1211.67	1206.82	1175.60	1242.83	668.635	0.90	0.51
True Adj Intensity[b]	1373.63	1363.45	1365.11	1371.86	891.647	0.92	0.98

[a] OC = Odor Concentration-European standard relative to a n-butanol standard

[b] True values have been corrected for background of incoming air

Table 7. Effect of week of production on human olfactometry readings from air collected from a wean-finish confinement building.

Dietary phase:	Nursery	Grower 2	Finisher 2		P Values
Week of production:	3	11	19	MSE	Wk of Production
Olfactometry					
Detection threshold, OU/m^3	1409.54	1375.39	1345.93	742.607	0.31
OC, oue/m^{3a}	1376.25	1325.71	1295.52	674.945	0.47
Intensity, full strength	2.98	2.77	2.71	0.391	0.07
Hedonic tone, full strength	-4.33	-4.10	-3.69	1.149	0.07
True detection threshold[b]	1227.02	1224.13	1188.30	683.015	0.24
True OUE[b]	1239.96	1212.07	1176.21	668.635	0.35
True Adj Intensity[b]	1668.75	1275.25	1165.14	891.647	0.28

[a] OC = Odor Concentration-European standard relative to a n-butanol standard

[b] True values have been corrected for background of incoming air