Title: The Effect of Air Quality in Swine Finishing Facilities Upon Animal Performance and Environmental Pollution Potential - **NPB #01-128**

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I. Abstract

This project was conducted with 96 finishing pigs in 4 identical rooms under closely controlled ventilation and temperature. The objectives of the project were to determine if air quality impacted pig performance, to identify and quantify the gasses emitted and to determine emission rates of those gasses, and to compare gasses, dust, and performance as influenced by three different levels of ozonation in the facility. The emission rates were calculated and tabulated. The gasses detected were too numerous to detail here but are detailed in the dissertation produced in conjunction with this project (Kim-Yang, 2002). Overall performance of the pigs was not affected although feed intake and gain were reduced in the early stages at the highest ozone level. The differences were overcome by later compensatory gain and there was no difference in the end. The ozone linearly decreased odor detection thresholds as measured by the amount of dilution when odor is first detected by a trained odor panel (dilution threshold). Ammonia, indole, and skatole were linearly reduced by ozonation. P-cresol was reduced quadratically with a minimum at 0.05 ppm ozonation, but the other gases analyzed in detail (hydrogen sulfide, phenol, and p-ethyphenol) were not affected. Dust levels on average increased quadratically with ozone with a maximum at 0.05 ppm.

II. Introduction

Historically the swine industry has reacted to public environmental concerns in consideration of legal ramifications. However, producers generally react most quickly to information leading to an economic advantage. Economic benefits are derived from performance enhancement, and if performance is improved by conditions that result in more environmentally friendly production conditions, the economic incentive is in place to do so.

Beyond delving into the possibility of economic advantages, it would be useful to know what the concentrations are of some of the key gases and bioaerosols emanating from an environmentally controlled setting. Furthermore, information and methodology for estimating the emissions of gases from swine facilities is incomplete, and the industry would benefit by having more complete information.

III. Stated Objectives from original proposal

1. To determine the effects of air quality and bioaerosol contamination on the lean, high growth potential pig of the 21st century.
2. To determine key gas levels and bioaerosol contaminants as influenced by the management strategies of the manure handling and ventilation systems in an environmentally controlled setting.
3. To provide a more complete profile of gaseous and bioaerosol contamination levels which will allow a more accurate determination of air emissions from swine finishing facilities and their potential for environmental pollution.

III. (mod) Modified Objectives

The stated objectives from the original proposal were modified as noted on the Interim Report on NPB #01-128, submitted October 30, 2001. They are as follows.

1. To determine the effects of air quality and bioaerosol contamination on the lean, high growth potential pig of the 21st century. (unchanged from original)
2. To determine key gas levels and bioaerosol contaminants in an environmentally controlled setting. (As stated in the interim report, we were unable to achieve the desired ammonia concentrations in the facility due to animal use and care limitations on ventilation control. Hence, only one management strategy is reflected.)
3. To provide a more complete profile of gaseous and bioaerosol contamination levels which will allow a more accurate determination of air emissions from swine finishing facilities and their potential for environmental pollution. (unchanged from original)
4. Compare gas levels and performance parameters between the control and ozonated treatments. (As stated in the interim report, this experiment was run simultaneously with one in which ozone was injected at three different concentrations. Comparisons will be reported.)

IV. Materials and Methods

Four large environmental chambers located at the Michigan State University Farms were renovated to allow in-depth analysis of the effects of the gaseous constitution and bioaerosol contamination in a controlled environment. It was intended that the ventilation system and waste handling methods would be manipulated in an attempt to produce varying ammonia levels, but we were not permitted to control the ventilation system in order to cause elevated ammonia levels (interim report on NPB #01-128). Ventilation was fixed at approximately 600 cfm per room. Each room was approximately 360 ft^2, and the pull-plug manure holding system under the wire mesh floor was approximately 190 ft^2. Ventilation per pig was 25 cfm (compared to 24 to 35 cfm recommended[Midwest Plan Services, 1991]), and space per pig was 8 ft^2 (equaling the recommendation [Midwest Plan

Services, 1991]).

This experiment was part of a larger experiment with identical rooms receiving treatments of three different levels of ozonation with a control room with no ozonation. The injection rates of ozone were at concentrations of 0.01, 0.05, and 0.10 ppm. The control ozone level was ambient.

The statistical design for the research was a rotational randomized block. Twenty-four animals were placed in each of four pens at approximately 36 pounds and were taken for slaughter and analysis at approximately 238 pounds. Animals were placed in the trial on 6/11/01 and slaughtered 9/30/01.

Several methods of air sampling were employed. For the purpose of identifying gases and determining gas concentrations within the facility by spectrometric detection, samples were collected using solid phase microextraction (SPME) fibers in the methodology described by Kim-Yang (2002). The samples were analyzed on a Varian 3800 GC and 2000 MS. The GC column was a DB-5MS (J&W Scientific). More than 50 volatile organic compounds (VOCs) were identified, and five (phenol, p-Cresol, p-Ethylphenol, indole, and skatole) were chosen for in-depth analysis.

Ammonia and carbon dioxide concentrations were measured biweekly using Drager tubes, and hydrogen sulfide concentration was measured biweekly with a Jerome Analyzer. Drager tube measurements were taken at two different locations at 1.0 m height. Hydrogen sulfide measurements were taken at two different locations and at two heights (0.5 m and 1.0 m) in each room. Air for olfactometry analysis was collected using 10 L-Tedlar bags purchased from SKC Inc. All new bags were purged with high purity air three times prior to sampling. The bags were shipped overnight to Purdue University for analysis by a trained odor panel. The odor analysis was conducted the day following sampling. Odor analyses were conducted monthly. Odor intensity measurements were made at dilutions where the odor was first detected. Dilution to threshold (DT) is the ratio of the dilution air volume to sample volume when the panelists first detect odor.

Bioaerosol samples were taken using a MicroBio MB2 Air Sampler. Dust levels were determined bi-weekly using a Thermo MIE DataRam 4 dual wavelength nephelometer portable particle sizing aerosol monitor. Feed for the pigs was weighed and recorded when feeders were filled. Water consumption was measured with water meters and recorded biweekly. Pigs were weighed biweekly. Average daily feed intake, average daily water usage, average daily gain and feed: gain ratio were computed for each biweekly period.

The environment was closely controlled within the limits of the heating and air conditioning system capacity. The target temperatures were 77° F ±2° F initially ramping down linearly to 70 °F±2° F at the end. On two occasions temperatures were above 90°F for less than 2 hours due to power and/or air conditioning system failure, but never reached the intervention temperature of 95° F. Temperatures were monitored continuously with thermocouples connected to a Campbell Scientific datalogger and max/min thermometers. Ventilation rates were determined by hot-wire anemometers placed in ventilation ducts leading to the rooms. Manure handling was a shallow pit pull-plug fresh water recharge system.

V. Results

Gas Concentrations

The gas concentrations were determined as described in the materials and methods section. The values shown in Table 1 below for ammonia, carbon dioxide, and hydrogen sulfide are averages of all values taken on the date for the treatments shown.

Table 1. Ammonia, Carbon Dioxide, and Hydrogen Sulfide Concentrations (ppm)

Ammonia	7/02/01	7/17/01	7/31/01	8/13/01	8/27/01
Control	2.2	3.0	2.8	3.0	3.0
0.01 ppm	1.8	2.5	2.3	3.8	4.0
0.05 ppm	1.8	2.5	2.3	2.1	2.4
0.10 ppm	1.5	1.9	1.9	1.9	2.4
Carbon Dioxide					
Control	945	1050	750	725	905
0.01 ppm	950	1200	800	863	1038
0.05 ppm	880	888	888	725	750
0.10 ppm	1045	963	600	713	815
Hydrogen Sulfide					
Control	0.123	0.195	0.273	0.195	0.253
0.01 ppm	0.230	0.104	0.150	0.238	0.270
0.05 ppm	0.122	0.200	0.318	0.268	0.553
0.10 ppm	0.201	0.123	0.223	0.418	0.308

Table 2. Dilution thresholds (DT) and Volatile Organic Compounds inside building

Date	Ozone Concentration	DT	Compounds sorbed on SPME fiber (ηg) Phenol	p-Cresol	p-Ethylphenol	Indole	Skatole
7/6/01	Control	1086	107	117	2.07	0	0
	0.01	621	105	115	2.15	0.59	0
	0.05	386	9905	96.8	1.94	0	0
	0.10	327	9306	98.4	1.98	0	0
8/3/01	Control	808	144	353	2.93	7.26	19.85
	0.01	683	122	296	2.99	3.36	5.92
	0.05	683	118	297	2.76	1.34	1.40
	0.10	382	102	164	2.08	0	0
8/31/01	Control	1113	128	308	2.28	6.10	13.33
	0.01	799	147	430	2.69	3.04	9.22
	0.05	866	100	224	1.92	0	5.9
	0.10	676	110	366	2.33	0	0
9/28/01	Control	944	138	408	2.28	4.33	14.69
	0.01	734	89	229	1.17	0	1.71
	0.05	622	111	260	1.90	0.82	0.95
	0.10	317	89	192	1.71	0	0

Emission rates

Ventilation rates varied very little and remained between 550 cfm and 650 cfm per room. The ventilation rate was fixed at 600 cfm for emission rate calculation purposes. Table 2 below shows typical concentrations during the final phase of the trial when the values were the greatest. The emission rate was calculated as the product of the concentration and ventilation flow rate with appropriate units conversion.

Table 3. Typical Gas Concentrations (ppm or μg/L) and Emission Rates (g/h) for ventilation at 600 cfm.

Gas	Hydrogen Sulfide (ppm)	Ammonia (ppm)	Carbon Dioxide (ppm)	Phenol, (μg/L)	p-Cresol, (μg/L)	p-Ethyl-phenol (μg/L)	Indole (μg/L)	Skatole (μg/L)
Concentration	0.19	3.0	900	13	11	0.04	0.11	0.50
Emission Rate (g/h)	0.29	2.46	1001	13.3	11.2	0.04	0.11	0.51

[1] Carbon dioxide entering concentration was approximately 400 ppm.

Respirable Dust

Table 4. Respirable dust (<2.5 µm diameter)

Ozone	0.00	0.01	0.05	0.10
date				
7/3/01	34.1	48.4	43.0	67.6
7/17/01	97.7	100.2	114.4	103.7
7/31/01	73.1	75.5	98.0	93.7
9/1/01	56.1	78.9	114.3	127.6
9/13/01	85.6	76.7	89.9	93.0
9/25/01	127.3	110.3	218.5	143.3

shown as mass of dust per cubic meter of air ($\mu g/m^3$)
for particles smaller than 2.5 µm

Performance Measures

Performance measures: 1) weight gain , 2) feed intake, and 3) water intake were calculated for the respective two-week periods. The performance measures for each respective two-week period are average daily gain shown in Table 5, average daily feed intake shown in Table 6, average daily water intake shown in Table 7, and feed: gain ratio shown in Table 8.

Table 5. Average Daily Gain (lbs)

Ozone		0.00	0.01	0.05	0.10
Period	Starting weight(lbs)				
ACC-HAB	36.2	1.45	1.40	1.28	1.29
1	55.1	1.78	1.59	1.59	1.52
2	77.9	1.98	1.75	1.98	2.02
3	105.0	1.77	1.93	1.76	1.92
4	130.8	1.96	2.13	2.37	2.15
5	160.9	1.87	2.17	1.79	1.89
6	189.6	2.08	2.05	1.90	2.06
7	218.2	1.69	1.74	1.75	1.72
Overall		1.64	1.67	1.64	1.66

[1] ACC-HAB is the accommodation/habituation period from 6/15/01 to 6/25/01

[2] Periods shown are respective two-week periods beginning 6/25/01

Table 6. Average Daily Feed Intake (lbs)

Ozone		0.00	0.01	0.05	0.10
period	Starting weight(lbs)				
ACC-HAB	36.2	2.78	2.55	2.38	2.13
1	55.1	3.84	3.54	3.40	3.46
2	77.9	3.99	4.14	4.38	4.53
3	105.0	5.15	4.79	4.83	5.30
4	130.8	5.00	5.37	5.60	5.40
5	160.9	5.78	6.04	6.01	5.84
6	189.6	6.24	6.67	5.94	5.95
7	218.2	7.63	8.02	7.77	7.31
Overall		5.05	5.14	5.05	4.99

[1] ACC-HAB is the accommodation/habituation period from 6/15/01 to 6/25/01

[2] Periods shown are respective two-week periods beginning 6/25/01

Table 7. Average Daily Water Intake (gal)

Ozone		0.00	0.01	0.05	0.10
period	Starting weight(lbs)				
ACC-HAB	36.2	0.74	0.70	0.56	0.60
1	55.1	0.91	1.00	0.81	0.92
2	77.9	1.00	0.97	0.89	0.95
3	105.0	1.13	1.14	1.08	1.11
4	130.8	1.13	1.24	1.14	1.14
5	160.9	1.21	1.34	1.16	1.31
6	189.6	1.03	1.22	1.07	1.19
7	218.2	1.32	1.44	1.31	1.35

[1] ACC-HAB is the accommodation/habituation period from 6/15/01 to 6/25/01

[2] Periods shown are respective two-week periods beginning 6/25/01

Table 8. Feed: Gain Ratio

Ozone		0.00	0.01	0.05	0.10
period	Starting weight(lbs)				
ACC-HAB	36.2	1.91	1.82	1.86	1.65
1	55.1	2.16	2.23	2.15	2.28
2	77.9	2.02	2.36	2.22	2.25
3	105.0	2.91	2.48	2.74	2.76
4	130.8	2.55	2.52	2.37	2.52
5	160.9	3.09	2.79	3.36	3.08
6	189.6	3.00	3.25	3.13	2.89
7	218.2	4.51	4.62	4.43	4.25
Overall		3.07	3.07	3.08	3.01

[1] ACC-HAB is the accommodation/habituation period from 6/15/01 to 6/25/01 218.2

[2] Periods shown are respective two-week periods beginning 6/25/01

Discussion

Objective 1 was to determine the effects of air quality on the pigs. An assessment of air quality was made as shown in Tables 1 and 2. There were some differences in air quality as characterized by differences in concentrations of gases as shown in Tables 1 and 2. Objective 4 is addressed in the comparison of results under ozonation. Ammonia, for example, decreased linearly with ozone concentration and a linear model accounts for 94% of the variation within the range of concentrations observed. Respirable dust through twelve weeks of the trial was also influenced by ozone with a second order increase in respirable dust with ozone concentration. A quadratic model accounts for 99% of the variation in dust with a maximum at 0.05 ppm ozone. Average dilution to threshold (DT) for odor decreased with ozone concentration, and a linear model explains 85% of the variation in DT. Two (indole and skatole) of the five VOCs chosen for in-depth analysis were linearly reduced by ozone, and p-cresol was quadratically reduced by ozonation with a minimum at 0.05 ppm. The quadratic model for p-cresol accounts for 96% of the variation. The performance of the pigs as indicated by the performance measures noted in Tables 5-8 is mixed. Average daily feed intake for the first two periods was affected by ozone with the higher ozone levels leading to lower feed intake. This led to decreased average daily gain. In later periods there appeared to be compensatory gain, and by the end of the trial there was no difference.

Objective 2 (as modified) was to determine key gas levels and bioaerosol contaminants in an environmentally controlled environment. In this experiment the space per pig was 8 ft^2, and the ventilation was 25 cfm per pig. The typical gas concentrations are shown in Table 3, and they are relatively low. Hydrogen sulfide was less than 0.2 ppm, ammonia was about 3 ppm, and carbon dioxide was about 900 ppm. Concentrations of the five VOCs ranged from 0.04 µg/L (p-Ethylphenol) to 13 µg/L (Phenol). With the ventilation rate at 600 cfm, the emission rates for the gases, as called for in Objective 3, were calculated and are shown in Table 3. They varied from less than 0.04 g/h (p-Ethylphenol) to more than 1000 g/h (carbon dioxide). This relates to nearly 42 g/h per pig of carbon dioxide emission.

Objective 3 was to provide a profile of gaseous and bioaerosol contamination levels leading to determination of air emissions from the facility. The calculated emissions rates for the conditions as described are shown in Table 3. A complete listing of the compounds and their respective concentrations as identified by mass spectroscopy are listed in Kim-Yang (2002).

Summary

This project was conducted with 96 finishing pigs in 4 identical rooms under closely controlled ventilation and temperature. The objectives of the project were to identify gases emitted and determine their respective emission rates in a control room with fixed ventilation and temperature control through air conditioning and heating. Simultaneously, three other identical rooms were subjected to ozone injection rates at three different levels corresponding to 0.01, 0.05, and 0.10 ppm concentration. Pig performance was evaluated under each of the conditions, and gas concentrations, dust, and odor detection were evaluated in each of the rooms. A complete description of the gases can be found in the PhD dissertation by Kim-Yang (Kim-Yang, 2002). The ozone did not affect overall performance of the pigs but did linearly reduce odor detection thresholds, ammonia, indole, and skatole. Dust increased to a maximum at 0.05 ppm ozonation, and p-cresol was reduced to a minimum at 0.05 ppm ozonation. The other gasses chosen to be analyzed in depth (hydrogen sulfide, phenol, and p-ethyphenol) were not systematically affected by ozonation.

References:

Kim-Yang, Hyesoon. 2002. Characterization of odorous and hazardous gaseous compounds in livestock building air. Ph.D. Dissertation. Michigan State University.

Midwest Plan Services, 1991. Swine Housing and Equipment Handbook. MWPS-8, Fourth Edition. Midwest Plan Service, Ames, Iowa. ISBN 0-89373-054-8.