Field Performance of a Pit Additive Tested in Commercial Grow-Finish Houses

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Most of the pigs produced in Indiana are finished in large enclosed buildings with slotted floors and long term underfloor manure storage. Of the 130 trace gases in the air of animal houses, concentrations are known for only 23 (Hartung and Phillips, 1994), of which NH_3, CO_2 and H_2S are the most important. However, most of the quantitative information, especially on emission rates, of these three gases in large swine buildings is somewhat lacking. The reported NH_3 emission rates from swine houses range from 3.4 to 78.9 lb per 100 lb of live weight per year depending on housing types (Hartung and Phillips, 1994). Measurement of NH_3 emissions from large swine houses in North America has not been found in the available literature. The only reported field investigation of CO_2 emission was in Belgium with a small house of less than 70 pigs (Ni et al., 1996). Measured concentrations of H_2S in pig houses were from $3.75x10^{-8}$ to $1.25x10^{-6}$ lb/ft^3 (Muehling, 1970; Goedseels, 1973; and Hartung and Phillips, 1994), but emission rates were not determined. The objective of this research was to evaluate the effectiveness of a commercially available manure additive (Alliance™) to reduce noxious gas emissions from hog buildings and gas levels inside the buildings.

Procedure

Field tests of the manure additive were conducted in two buildings with growing and finishing pigs (Figure 1). These 1993 buildings had the following characteristics: (1) naturally-ventilated with inverted-V chimney roof and curtain sidewalls, (2) flat, 7’6” high ceiling with 5.5” blown-in insulation, (3) ventilation chimney 3’11” wide at the ceiling and 8” wide at the uncapped ridge with 5.5” batt insulation, (4) ridge closure consisting of a PVC tube controlled manually, (5) one-room, 40’x180’ building holding up to 1000 pigs that start at 55 lb each, (6) totally-slotted floor and no pit ventilation, and (7) all-in, all-out production.

These buildings had two air exhausts: the inverted-V shaped chimney, and the downwind sidewall curtain opening. However, the chimney is the sole exhaust of air a large percentage of the time, especially during cold weather, and exhausts air of the “average” condition during wind-induced crossflow. The chimney acts as a large sampling port and is relatively low (7’6” above the floor), 3’11” wide or 10% of the building width, near the human breathing zone, only 5’ above the pigs, and furthest from the fresh air inlets and noxious gas sources (e.g., fresh dung, underfloor slurry, animal breath, and floor litter).

The buildings were oriented E-W with the ends connected by a small work room. The east building was treated with additive and the west building was used as the control (no treatment).

Instrumentation was housed in a 6'7" x 15'1" clean environmentally-controlled instrument room constructed inside the work room.

The chemical solution was sprayed into the top of the pit creating an aerial mist in the headspace and covering the entire surface of the manure slurry (Figure 1, top). There was one nozzle in each of the 40 pens and spraying was controlled by a programmable logic controller. The spray cycle consisted of spraying alternate nozzles on each side of the barn for two minutes each, for a total cycle time of eight minutes and three cycles per day. The amount of chemical sprayed was 0.066% of the manure production of 9,920 lb per day.

Inside air was pumped continuously through two sampling lines at 0.21 cfm from inside each building into the instrumentation room. A six-port combining manifold was used with each line inside the building to mix filtered air from six locations (Figure 2). The first gas stream was obtained from six points located 6" beneath the floor in order to assess pit headspace concentrations. The second gas stream was obtained from six points along the length of the chimney to assess gas emission rates (Figure 1).

Ammonia was converted to nitric oxide (NO) with a solid state converter at 1607°F. The NO was measured with a chemiluminescence detector. Hydrogen sulfide was converted to sulfur dioxide (SO_2) that was monitored by the pulsed fluorescent technique. Carbon dioxide was measured with a photoacoustic infrared gas sensor. The gas instruments were calibrated twice weekly with specially-blended certified gases.

Each gas analyzer was switched sequentially between four ported manifolds (two per room) in the instrument room, and sampled from each manifold for 15 minutes. Data collected during the last ten minutes were averaged to determine gas concentration.

A ±0.1 iwg pressure sensor was utilized to measure building static pressure. A temperature and relative humidity probe with ±0.5°F and ±2.0% accuracy respectively, and protected by a radiation shield, was used for outside measurements. Wind speed and direction was measured with a 0.06 to 197 ft/s, three-dimensional, ultrasonic anemometer located 33' above the ground and 30' away from the building.

The determination of ventilation airflow rate in these naturally ventilated buildings with large slot openings necessitated the use of an indirect method. The heat balance method chosen for this project consisted of sensible heat lost by conduction through the building envelope, heat lost by ventilation airflow, and heat produced by the pigs. The heat lost from the building was estimated using standard heat conduction equations based on thermal resistances and building dimensions. The sensible heat produced by the pigs was estimated with heat production equations (CIGR, 1992) based on number and weight of the animals and the ambient temperatures measured near the pigs (Figure 1).

Gas emission rates were determined by multiplying the outlet gas concentration measured in the chimney outlet by the mass flow rate of ventilating air estimated by the sensible heat balance. Incoming concentrations of H_2S and NH_3 were negligible according to independent measurements.

Results

The results presented in this paper were obtained from experiments during 63 days, from January 27 to March 30, 1997. Data from the treated building and control building are compared in Table 1 and Figures 4-9. Table 1 provides the basic statistics of environmental parameters, gas concentrations, gas emission rates and airflow rates during this period of time.

Initially, there were 859 and 927 pigs in the treated and control buildings, respectively. Pig numbers decreased to 394 and 284 on March 30, 1997. Based on linear interpolation between incoming and outgoing weights, the pigs weighed 141 lb at the beginning and 242 lb at the end of experiment (Figure 3). Figures 4, 5 and 6 present the daily mean values of gas concentrations of NH_3, H_2S and CO_2. Figure 7 illustrates the hourly mean emission rates of NH_3 and H_2S per 100 lb of pig in a typical day. Figures 8 and 9 give the daily mean emission rates of NH_3 and H_2S per 100 lb of pig during the entire period. Daily averages of inside temperature (at the height of 1'8" above floor) and outside temperature are presented in Figure 10.

Daily mean NH_3 concentrations in the pits averaged 4±0.4 and 14.3±1.3 ppm in the treated and control buildings, respectively. Daily mean NH_3 concentrations in the chimney averaged 4.3±0.4 and 13.7±1.4 ppm in the treated and control buildings, respectively. The pit/chimney ratios of daily mean NH_3 concentrations were 0.93 and 1.04 in the treated and control buildings, respectively. In the treated building, NH_3 concentrations were greater in the outlets because the NH_3 reducing chemical had greatly reduced the fraction of the total ammonia produced that was from the pit. A greater portion of the total ammonia produced was derived from above the floor as compared to the control room.

Daily mean H_2S concentrations in the pits averaged 251±40 and 193±40 ppb in the treated and control buildings, respectively. Daily mean H_2S concentrations in the chimney averaged 190±39 and 166±40 ppb in the treated and control buildings, respectively. The pit/chimney ratios of daily mean H_2S concentrations were 1.32 and 1.16 in the treated and control buildings, respectively. The reason for higher concentrations in the pits was perhaps due to the relatively high density of hydrogen sulfide.

Daily mean CO_2 concentrations in the pits averaged 2884±228 and 3022±223 ppm in the treated and control buildings, respectively. Daily mean CO_2 concentrations in the chimney averaged 3249±250 and 3335±255 ppm in the treated and control buildings, respectively. The maximum numbers reported here are biased low because the concentrations frequently exceeded the 5000 ppm range of the CO_2 monitors. The pit/chimney ratios of daily mean CO_2 concentrations were 0.89 and 0.91 in the treated and control buildings, respectively. Carbon dioxide concentrations were probably higher in the chimney outlets than at the top of the pit headspace because the CO_2 generated above the floor from the pigs is greater than that generated from the stored manure (Ni et al., 1996).

The average NH_3 emission per pig was 1.45 lb/yr in the treated building as compared to 4.72 lb/yr in the control building. Thus the manure additive appeared to reduce whole house NH_3 emissions by 69%.

The average H_2S emissions per pig in the treated and control buildings were 0.13 and 0.12 lb/yr, respectively. We expected to observe an increased H_2S level as the NH_3 decreased because the basic NH_3 is known to react with the acidic H_2S. That no essential increase in H_2S was observed suggests that the manure additive was at least partially effective in controlling the toxic H_2S. However, since NH_3 production was reduced significantly, the H_2S production should have increased. Therefore, the manure additive was effective in counteracting the increased H_2S production that theoretically should have occurred. The hourly emission of H_2S was more variable than NH_3 as seen on February 26 (Figure 7).

The average CO_2 emissions per pig in the treated and control buildings were at 2910 and 3089 lb/yr, respectively. The emission from the treated building was 5% lower. The sources of CO_2 emission included animal respiration, manure release and combusting heaters. There were two 225 000 Btu/h liquid propane heaters.

Data reported in this paper are the initial results obtained during 63 days at one observation site. A total of four sites are presently being monitored, each for a period of 12 months. The latest data for these tests can be seen on the Purdue Pork Page at http://anr.ces.purdue.edu/porkpage.htm.

Applications

According to the data collected in this experiment, producers can expect up to 70% reduction in ammonia gas generation and concentration in their deep-pit finishing buildings with the use of Alliance. The other 30% is probably being emitted from the slats and above the slats which is out of reach of the applied spray. The product did not increase or decrease the hydrogen sulfide generation rate, although 30 to 50% reductions have been measured in more recent tests.

References

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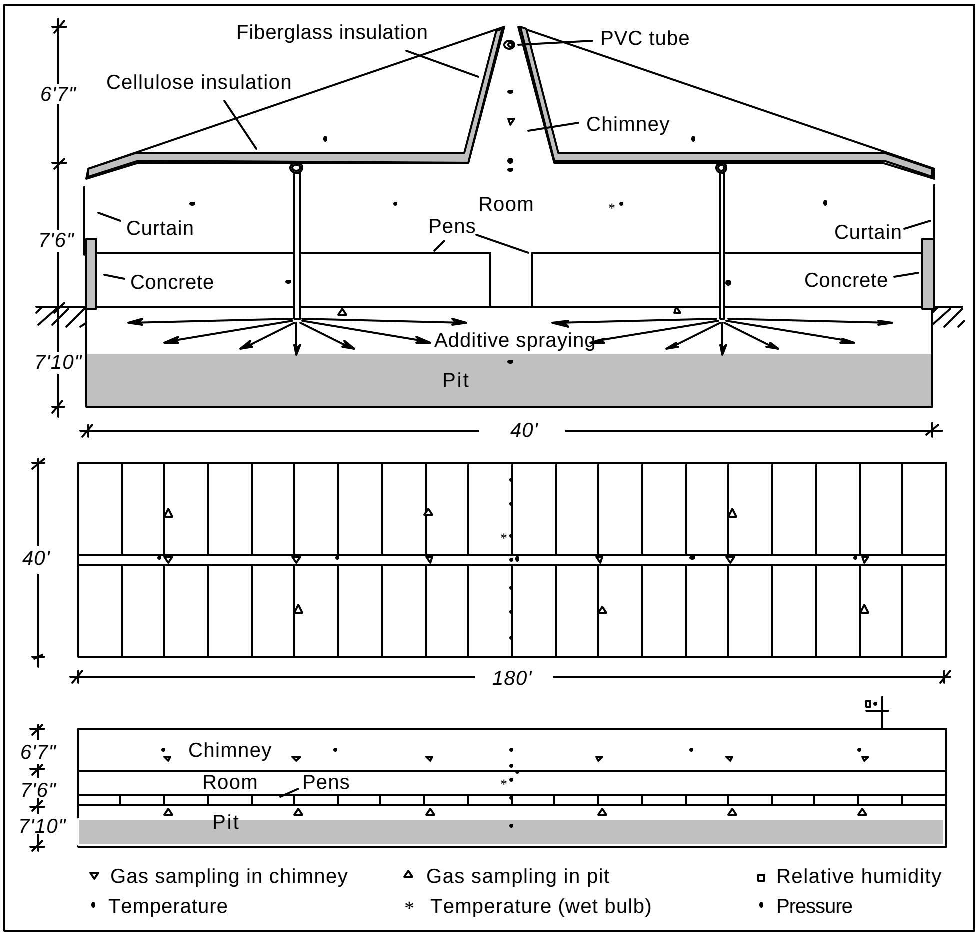

Figure 1. Cross section (top), floor plan (middle) and side view (bottom) of the treated building with sampling and measurement positions.

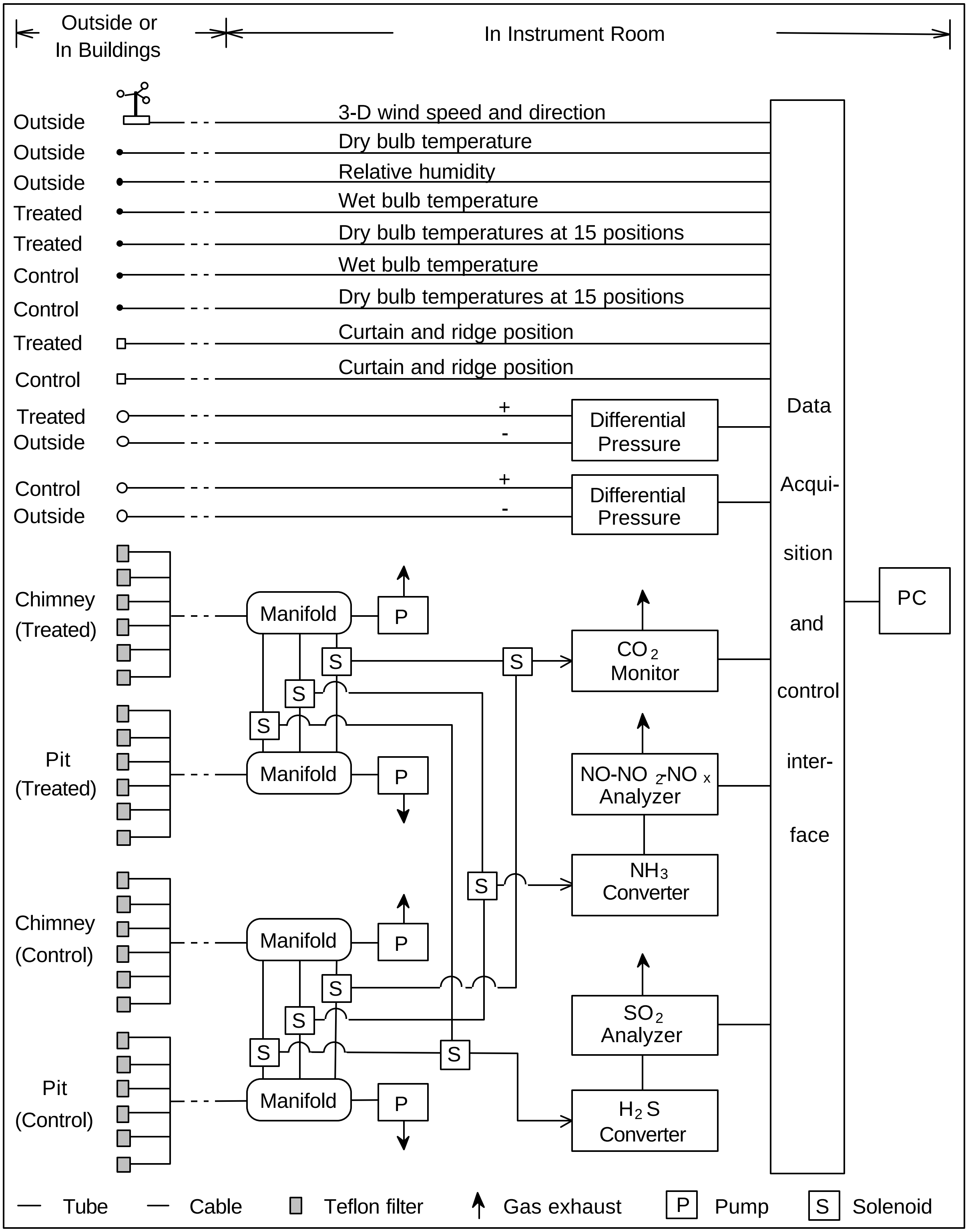

Figure 2. Configuration of the measurement setup for the treated and control buildings.

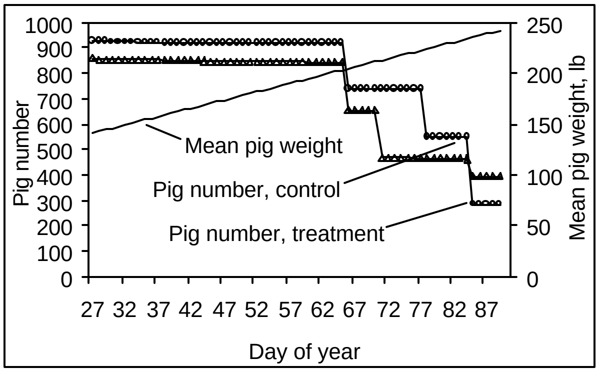

Figure 3. Pig numbers and pig weights in the treated and control buildings.

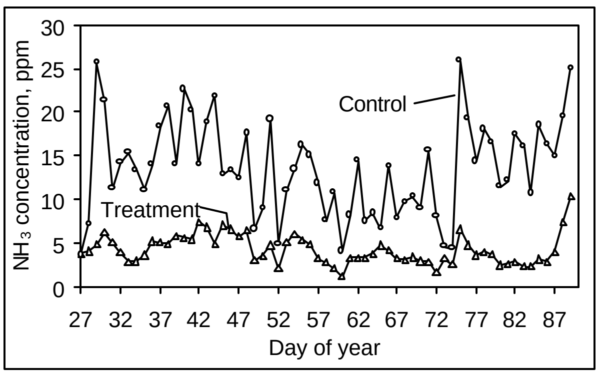

Figure 4. Daily mean NH_3 concentrations in the chimney in the treated and control buildings.

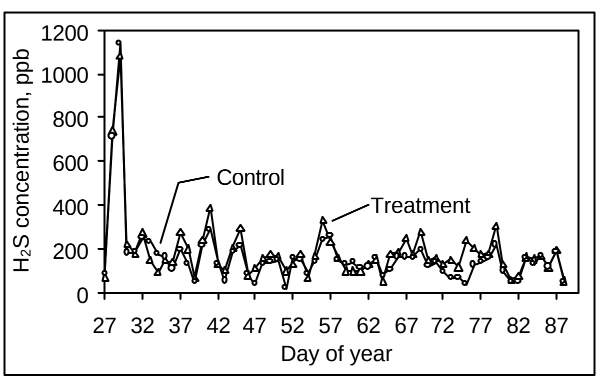

Figure 5. Daily mean H_2S concentrations in the chimney in the treated and control buildings.

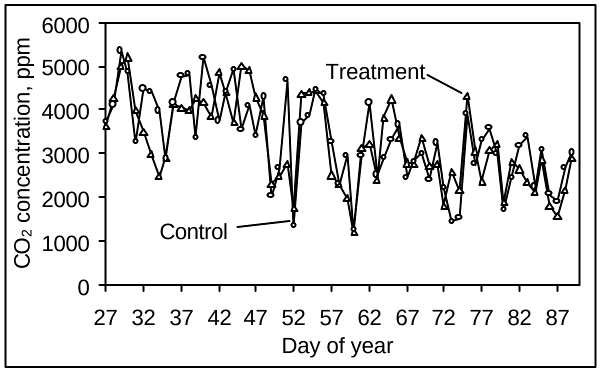

Figure 6. Daily mean CO_2 concentrations in the chimney in the treated and control buildings.

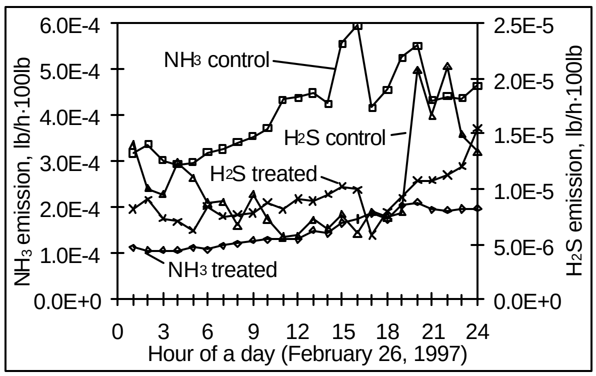

Figure 7. Hourly mean NH_3 and H_2S emissions per 100 lb of pig from the treated and control buildings in a typical day.

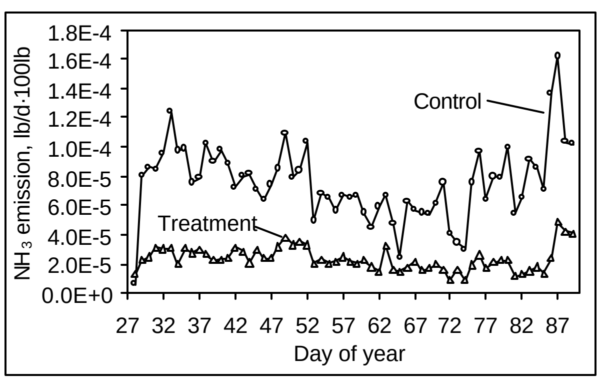

Figure 8. Daily mean NH_3 emission rates per 100 lb of pig in the treated and control buildings.

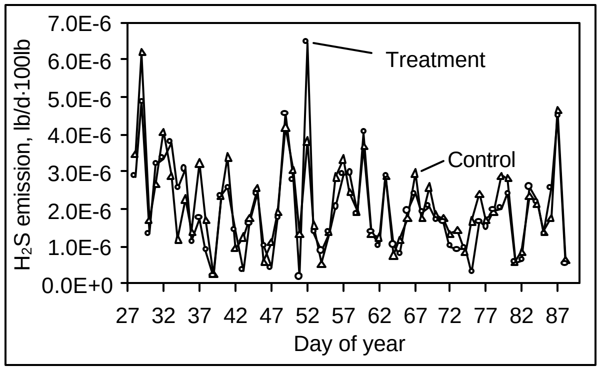

Figure 9. Daily mean H_2S emission rates per 100 lb of pig in the treated and control buildings.

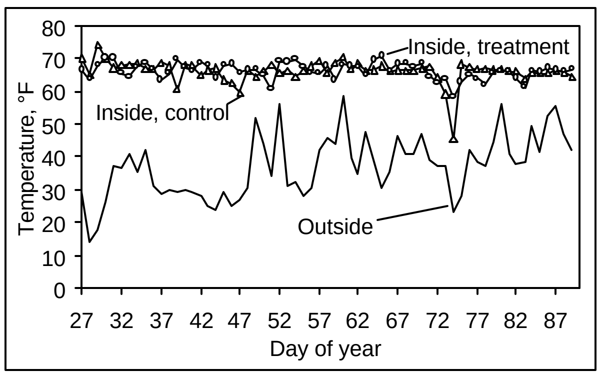

Figure 10. Change of inside and outside temperatures.

Table 1. Statistics for daily means of environmental parameters, gas concentrations, gas emission rates and airflow rates from January 27 to March 31, 1997 (95% confidence levels are shown as ± 2 standard errors).

Parameter	Treated building			Control building		
	Mean	Min.	Max.	Mean	Min.	Max.
Temperature, °F						
Outside	37±2.4	14.0	58.5	37±2.4	14.0	58.5
Attic	39±2.3	17.4	60.4	40±2.3	17.4	60.2
1’8” above floor	66.2±0.6	58.2	70.6	66.1±0.9	45.2	74.1
4’11” above floor	65.3±0.5	55.9	68.4	65.5±1	43.8	73.3
Chimney outlet	65.7±0.8	54.2	70.1	66.3±1.1	41.4	71.8
Relative humidity, %						
Inside	76±3	58	95	67±2	52	87
Outside	79±3	53	98	79±3	53	98
Pressure difference, Pa	-4.8±1	-19	0	-3±1	-17	3
NH_3 concentration, ppm						
in pit	4±0.4	1.3	11.8	14.3±1.3	3.6	26.5
in chimney	4.3±0.4	1.3	10.3	13.7±1.4	3.7	25.9
H_2S concentration, ppb						
in pit	251±40	23	1079	193±40	45	1150
in chimney	190±39	55	1081	166±40	23	1140
CO_2 concentration, ppm						
in pit	2884±228	776	4702	3022±223	1319	5344
in chimney	3249±250	1201	5211	3335±255	1251	5350
Gas emission rates						
NH_3, lb/yr·pig	1.45±0.18	0.44	4.59	4.72±0.63	0.21	15.22
H_2S, lb/yr·pig	0.13±0.02	0.01	0.44	0.12±0.02	0.01	0.42
CO_2, lb/yr·pig	2910±249	1452	7301	3089±252	1216	6264
Airflow rates, ft^3/h·pig	1056±179	330	3872	1091±180	227	3438