Title: Longitudinal evaluation of the effect of ventilation and environmental management of swine barns on *Salmonella* prevalence in finishing swine **NPB #05-041**

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Abstract:

There is a critical need to identify whether there are cost-effective pre-harvest interventions for control of *Salmonella*. Particularly attractive are interventions that would have animal health and performance benefits, allowing producers to recoup investments for *Salmonella* control from improved production efficiency. Previous work has indicated that there is an association between season and/or environmental temperature and *Salmonella* prevalence in finishing swine. What makes further evaluation of this risk factor promising is that there are production performance and pig health advantages to maintaining proper ventilation for swine buildings, which could help off-set extra costs associated with improvement in ventilation engineering and management. Five placements of finisher pigs in three barns were sampled monthly to determine the association between the barn environment (temperature, relative humidity, ammonia and duct concentrations) and *Salmonella* shedding in swine. Barns were divided into 12 regions fro the purposes of monitoring environmental parameters and determining *Salmonella* prevalence. All barns were *Salmonella* positive, and regional fecal prevalence averaged 4.9% (range 0-62.5%). Pigs in the early finisher stage (~10-11 weeks old) were at greater risk to shed *Salmonella* when the regional temperature was less than 75^{o}F. Late finishing phase swine (18-22 weeks old) in a region that had a temperature greater than 75^{o}F had a greater *Salmonella* prevalence than those in a region at temperature less than 75^{o}F. No association between relative humidity, ammonia concentration or dust concentration and *Salmonella* prevalence was found in this study. These data hold promise for designing interventions pre-harvest that have positive impacts on swine health, production performance and food safety.

Introduction:

There is a critical need to identify whether there are cost-effective pre-harvest interventions for control of *Salmonella*. Particularly attractive are interventions that would have animal health and performance benefits, allowing producers to recoup investments for *Salmonella* control from improved production efficiency. Previous work by our group and others has indicated that there is an association between season and/or environmental temperature and *Salmonella* prevalence in finishing swine. [1,2] Groups of finisher pigs in North Carolina USA with high *Salmonella* prevalence were at greater odds to have been sampled in winter and spring (approximately late November through late June).[1] In the same study, pigs reared during periods of large variability in daily high temperature were at greater risk to have high *Salmonella* prevalence.[1] These results are similar to others who reported increased seroprevalence during the Fall and Winter in Danish swine.[2] Cool weather ventilation is a compromise between maintaining adequate air exchange while conserving heat that may result in periods where ventilation is not optimal. Unpredictability of weather conditions during variable weather conditions makes proper setting of ventilation systems difficult. Improper ventilation or temperature stress might be a biological explanation for the association with *Salmonella* prevalence. What makes further evaluation of this risk factor promising is that there are production performance and pig health advantages to maintaining proper ventilation for swine buildings, which could help off-set extra costs associated with improvement in ventilation engineering and management.

Horizontal transmission of *Salmonella* by aerosol has been demonstrated in poultry, with suggestions that air flow patterns are an important component of promoting spread between animals.[3-9] Previous investigators have demonstrated that pigs are susceptible to *Salmonella* infection by the nasal route[10,11] In the only experimental investigation of aerosol spread in pigs[12], pigs that had potential nose to nose contact as well as aerosol contact with infected pigs became infected, but pigs that only had aerosol contact did not become infected. This study is limited by the fact that the experimental conditions were unlikely to reflect the typical airflow and dust concentrations found in US confinement facilities, as the aerosol contact occurred through a small hole in the wall between rooms of pigs. It is generally believed that *Salmonella* are carried on dust particles in the barn environment and that decreasing dust concentrations may decrease the risk of transmission of *Salmonella* within the barn environment.[13] These data suggest that *Salmonella* traveling on dust particles transmitted in the air in the barn environment may be an important source of *Salmonella* and that dust mitigation may be important not only for animal and occupational health, but also for *Salmonella* control.

Another measure of the air quality in swine environments is ammonia concentration. High ammonia concentrations can have negative impacts on production performance and animal health, in particular at high concentrations it can interfere with normal mucocilliary function, which may increase the probability of infection by the aerosol route.[14] Ammonia concentrations in swine environments may be associated with *Salmonella* transmission, either as a proxy measure of general air quality management, or as an actual biological factor by promoting infection by aerosol due to impaired innate immune function.

Objectives:

Objective 1: *Longitudinally describe the environment during the finishing phase in commercial swine finisher barns. The approach* was to monitor the growing swine environment for thermal (temperature and humidity) and air quality (dust and ammonia) measures in 5 swine finishing barns.

Objective 2: Determine the association between environmental parameters and Salmonella prevalence. The approach was to longitudinally sample finisher swine (using fecal culture) and to utilize time series analysis to evaluate the association between thermal environment and *Salmonella* pen prevalence.

Materials & Methods:

One Ohio swine production system was selected for participation. In each of three finisher barns, 12 regions representing 4 pens were established (48 pens/barn, 24 pens per side with a central alley). The barn inventories were approximately 960-984 pigs (20-22 pigs per pen). The barns all had concrete slatted flooring with manure storage below, curtain sides and tunnel ventilation capabilities for high temperature periods. Barns were also equipped with heaters and drip cooling.

For Barn 1, three consecutive groups of finisher pigs were sampled, and for barns 2 and 3, one turn was sampled for each barn. For each month of placement, 96 individual fecal samples were obtained from the barn, 8 samples per region (2 per/pen). Fecal samples were cultured using standard techniques. At the same time period, the following environmental measures were obtained: temperature (point estimate at time of collection, average temperature for the day, average temperature for the previous month for collections 2-4), relative humidity (point estimate at time of collection, average temperature for the day, average temperature for the previous month for collections 2-4), dust (point estimate at time of collection) and ammonia (point estimate at time of collection) concentrations. The unit of investigation was fecal prevalence at each collection period for each region.

Statistical analysis: Basic descriptive statistics for barn environment parameters were calculated and graphically displayed. Each regional fecal prevalence estimate was the outcome measure and conducted the Kruskall Wallace test (STATA ver. 8.1) to compare prevalence between regions based on environmental parameters. Temperature was dichotomized into equal to or greater and below 75 ^{o}F. For humidity, 80% was the cutoff value, as humidity above 80% is considered the upper bound for swine housing. For ammonia concentrations, the cut-off value was set at 10 ppm. For dust concentrations, high dust concentration was defined as concentrations above 2.5 mg/m^3.

Results

Objective 1: *Longitudinally describe the environment during the finishing phase in commercial swine finisher barns.*

Thermal environment: Figures 1-3 demonstrate the temperature reading within barns at each region for each month of collection. Of interest is that there can be as much as 10^{o}F difference between different regions of the barn at the same time of measurement. Additionally, based on recommended temperature ranges for pigs for their age at each collection, regional measurements of temperature were out of recommended temperature range (either too cool or too hot) 20% of the time.

Relative humidity: In these barns, relative humidity ranged from 23.8-100%, with an average of 78.1%. Relative humidity was above 80% in 19.8% of the regional measurements.

Dust concentrations: We were able to collect total dust measurements for Barns 1 and 2. F. Concentrations ranged from 0.03-13.1 mg/m^3. The average dust level was 1.69 mg/m^3. For 24 of 132 (18%) regional dust measurements, the total dust concentration was above 2.5 mg/m^3.

Ammonia concentrations: Ammonia concentrations ranged from 0.2-30 ppm for all regional measurements. For 56/184 measurements (30.4%) the ammonia concentration was above 10 ppm.

Objective 2: Determine the association between environmental parameters and Salmonella prevalence.

All turns of pigs were positive for *Salmonella* for at least 2 of the collection periods (One turn was positive at 2 sampling periods, the other 4 were positive at 3 sampling periods). There were 60 regions measured (5 turns X 12 regions/turn).

Of these 60 regions, 9 regions were positive at 2 collection periods. None were positive more than twice. For all possible outcomes (region X collection X barn), 20% of the time they were *Salmonella* positive. The overall individual fecal prevalence was 4.9%, with regional prevalence ranging from 0-62.5%.

Ten-week-old pigs that were housed in regions where the point temperature was less than 75^{o}F had a significantly greater prevalence of *Salmonella* than pigs held at or above 75^{o}F (1.7% vs. 0.9%, $p<0.005$). For pigs in the 18-22 week old range, pigs that were housed in regions that the point temperature was above 75^{o}F had a higher prevalence of *Salmonella* than pigs housed at temperature at or below 75^{o}F (16.9% vs. 6.1%). There was no difference in *Salmonella* prevalence for 14-week-old pigs based on point temperature. There were no significant differences in *Salmonella* prevalence for the average day temperature or average month temperature for a region. There were no significant differences in regional *Salmonella* prevalence based on humidity, ammonia or dust concentrations.

Discussion:

These data support that the thermal environment of swine barns is associated with *Salmonella* prevalence. In young pigs, where chilling is the greater thermal risk, pigs sampled on days that barn temperature was below 75^{o} F had higher prevalence. Conversely, older pigs that are at greater risk of heat stress had higher *Salmonella* prevalence when sampled at temperatures above 75 ^{o}F. The lack of association of averaged temperatures is likely a wash-out effect of inclusion of the entire time period or a reflection that the temporal components of the induction period from the thermal stress to the increase in *Salmonella* shedding is short. Further analysis of temperature data, including averages of daily high, daily lows and any extreme values are on going. The lack of an association between *Salmonella* prevalence and relative humidity, dust and ammonia suggests that at least the association between these measures of environmental quality is not as strong as that of temperature. Limitations of ammonia and dust measurements are that they were taken only on the day of sampling, so if there was any induction period associated with these parameters less than a month in duration, we could not measure them. Comparing previous months values of ammonia and dust resulted in so few samples that power to discern a difference was exceptionally low for this study.

It is interesting that heat stress was identified as a risk in this study, as previous studies had identified Fall and Winter seasons and high temperature variability (typical in Fall and Spring) as the high risk periods. This may suggest either regional variability or potentially geographic/farm differences in barn design and/or management of environmental temperature for swine. Further studies of the association between thermal environments on multiple farms in different regions are warranted.

Understanding the impact of the thermal environment has at least 2 potential positive outcomes for producers and pre-harvest *Salmonella* control. First, appropriate management of the thermal environment is associated with improved production performance and decreased risk of disease. Improved barn design and environmental management may benefit swine health, production performance, and food safety. Additionally, if pigs reared under suboptimal temperature conditions can be identified; it may provide potential interventions on farm or during processing that can be preferentially targeted at these high-risk populations. Further studies to understand the induction time associated with temperature stress will assist in timing of interventions if available.

Lay Interpretation:

These data suggest that environmental temperature; in particular lower environmental temperatures in early finisher pigs and high environmental temperature in older finisher pigs are associated with increased *Salmonella* prevalence. This holds promise for designing interventions pre-harvest that have positive impacts on swine health, production performance and food safety. Further studies to understand the impact of environmental management of swine barns under different building designs and different geographical regions are needed. Furthermore, more intensive monitoring of both the barn environment and *Salmonella* shedding is necessary to understand the time period between suboptimal thermal conditions and *Salmonella* shedding in swine.

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Figure 1. Distribution of point temperatures in Barn 1 for each month of collection.

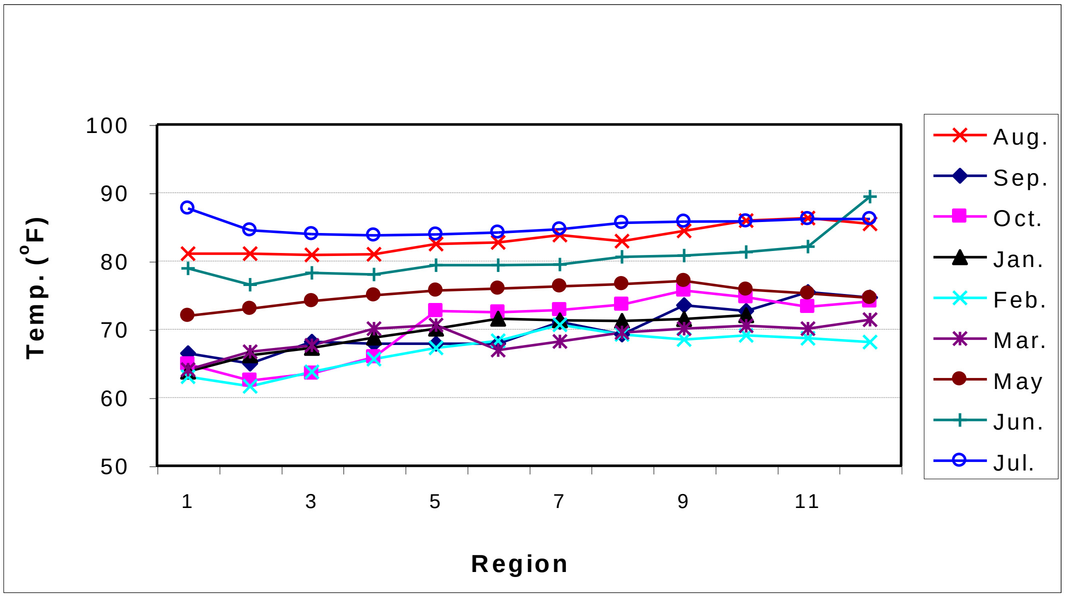

Figure 2. Distribution of point temperatures in Barn 2 for each month of collection.

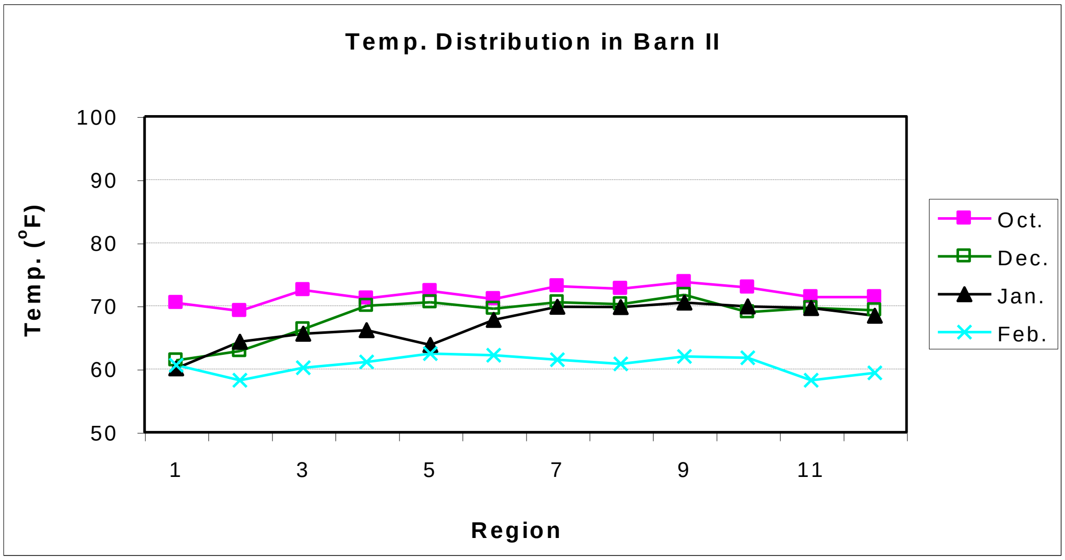

Figure 3. Distribution of point temperatures in Barn 3 for each month of collection.