Use of the heat index to predict increases in swine condemnations in slaughter surveillance data

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Abstract

The United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS) conducts weekly surveillance of slaughter condemnation rates for the purposes of early warning for emerging diseases and monitoring of health trends in swine. This retrospective observational study used the heat index (HI), which combines the effects of temperature and humidity, to predict the incidence and risk of death among swine in-transit and just prior to slaughter in the U.S. The risk of death for market swine at an HI between 93-106F was 1.17 times greater than at average temperatures between 54-79F. The risk of death for cull sows at an HI between 93-106F was 2.26 times greater than at an average temperatures between 54-79F. Roaster swine, however, were less likely to die when the HI was 93-106F compared to average temperatures ranging from 54-79F (risk ratio = 0.12). As a result of this study, weekly estimated HI values for slaughter establishments will be incorporated into the USDA, APHIS swine condemnation surveillance so analysts can correlate signals (noteworthy increases above baseline) for 'dead' condemnations with high HI values.

Keywords: *swine surveillance, swine condemnations, heat index, in-transit swine death*

Introduction

As part of an early warning surveillance system, the United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS) conducts weekly surveillance of condemnation rates for specific reasons at federally inspected swine slaughter establishments across the country. The purposes of this surveillance are to identify noteworthy increases (signals) above baseline condemnation rates/counts in near real-time that may indicate the emergence of disease and to monitor health trends. These signals may warrant further investigation to determine their cause. Surveillance analysts have noted signals for the condemnation reason 'dead' are most frequent during the summer months.

Pig deaths in transit or in pens just prior to slaughter ('dead' condemnations) are an animal welfare issue, a potential indicator of disease, and are an economic loss to producer, transporter and slaughter establishments (1). Factors associated with pig death during transport or at the slaughter establishment prior to slaughter include genetics, handling before they are transported, disease, poor health, stress and conditions during transport (2). High ambient temperature combined with high humidity is one of the most important environmental conditions contributing to in-transit death loss of swine heading to slaughter (1). Low temperatures can also lead to increases of in-transit death loss, however, this study focused on the effect of high temperatures and humidity. Other conditions during transport that affect the mortality and morbidity of pigs include length of the journey, density of pigs on the trailer, type of trailer, presence of bedding and wait time at the slaughter establishment (2,3,4).

The purpose of this study was to explore the relationship between the heat index (HI) (a measure of the combined effects of temperature and humidity of the air, also known as the apparent temperature) near the slaughter establishment during the week of slaughter and swine condemnations for the reason 'dead'. Potentially important variables that might modify the relationship between 'dead' condemnations and the HI such as swine type (market, roaster, cull sows) and slaughter establishment processing volume were included in the analysis. A better understanding of the impact of the HI on swine condemnations for the reason 'dead' will improve the interpretation of signals that occur during analysis of surveillance data and will help to guide the need for follow up investigations associated with these signals.

Materials and methods

The USDA's Food Safety and Inspection Service (FSIS) Public Health Information System (PHIS) contains information about swine inspection at FSIS-inspected slaughter establishments. Variables in the database include the week of condemnation or slaughter, swine class, reason for condemnation, number of head condemned by week, and number of head processed by week. APHIS has a Memorandum of Understanding (MOU) with FSIS to allow access to this data in PHIS. This analysis used six years of PHIS slaughter and condemnation data from January 2010 to December 2015.

The effects of the HI on three classes of swine were studied. Roaster swine are small, weigh less than 220lbs and are often used for whole carcass roasting. Market swine typically weigh between 220-260lbs. Cull sows are the female breeding swine removed from the farrowing herd, with an average weight above 400lbs. We did not include cull boars in our study because their numbers in the data were too low for meaningful analysis.

After merging tables and assigning weather data, 8% of slaughtered swine were lost from our original dataset. Remaining in was a dataset that included 4.2 million roaster swine, 619.2 million market swine, and 17.4 million cull sows from 149 different federally inspected slaughter establishments throughout the United States during our study period.

'Dead' loss ratios (DLR) were calculated for all swine each month by dividing the number of 'dead' condemnations by the total swine and multiplying by 100. This provided the incidence of 'dead' condemnations over the study period.

Establishment processing volume (number of head slaughtered) was recorded for each week and used as a predictor variable for condemnations to fit a cubic smoothing spline. Observing this spline, we were able to break up this continuous variable into five categories to group values with similar effects on condemnations. This new categorical variable was used as a random effect in our model to help account for the variability among the different plant sizes.

Weather information was taken from the website Wunderground.com via the R package "weatherData" (5). Using the Haversine Formula, which calculates the distance on a sphere using longitude and latitude, we recorded the closest weather stations for each slaughter establishment. To estimate the temperature and humidity for each slaughter establishment for each week of slaughter data, the average daily temperature and humidity were taken from the closest 1-3 weather stations within 100 miles.

The HI was calculated using the average temperature and humidity for the week (6). Once these values were obtained, they were categorized similarly to processing volume but this time included an offset term equaling the log of total swine slaughtered. This effectively weighted our observations based on volume so that slaughter plants that processed more swine were more influential in our regression. The three HI categories were 80 to 84F, 85 to 92F, and 93 to 106F.

The baseline temperatures ranged from 54-79F. This range was chosen because it excluded all of the records from our HI and temperatures below 54F, which was found to be the temperature at which cold starts effecting condemnation rate. To determine the estimated losses in each temperature category within both the baseline and HI groups, zero inflated negative binomial generalized linear mixed models (ZINBGLMM) were used. In this model, the number of pigs that were condemned for the reason 'dead' per week was used as a response variable, our categorical predictor variables were swine class and HI, and volume processed as a random effect. This was done using R with the "glmmADMB" package (7).

For categories of weekly HI, a condemnation rate (CR) was calculated for each swine class in a slaughter establishment. Multiplying the CR by 10,000 we calculated an Expected Incidence Rate (EIR). Using the results of a ZINBGLMM, a Risk Ratio (RR) was calculated to determine the increased risk when comparing categories of HI. This was done by taking the predicted CR, and dividing by the reference category (54-79F).

Results

With the HI formula used in this study only valid above 80F, we looked at temperature averages with our full dataset first. The DLR for all swine was 0.19% (19 pigs per 10,000 slaughtered). Disaggregating into the summer months we find the highest DLR to be in the months with the warmest average temperature, July and August (Table 1).

Table 1. 'Dead' loss ratios and average temperature by month 2010-2015.

	May	Jun	Jul	Aug	Sep
DLR (%)	0.183	0.197	0.228	0.236	0.204
AvG. Temp (F)	65.4	72.9	76.9	74.5	67.5
Range (F)	36-96	48-93	52-96	51-93	41-92

The HI model included 348,000 roaster swine, 24.8 million market swine, and 1.2 million cull sows at 131 different federally inspected slaughter establishments. These records were those we could apply the HI formula to. There was a significant effect ($p<0.05$) of HI on the CR in each of the swine types in our model (Table 2).

Table 2. Condemnation Rate (CR), Expected Incidence Rate (EIR), and Risk Ratio (RR) of 'dead' by heat index category for US Swine 2010-2015.

Heat Index (F)	Condemn rate	EIR (Per 10,000)	Risk ratio
Roaster			
54-79	0.00123†	12	1.00
80-84	0.00173†	17	1.41
85-92	0.00098†	10	0.80
93-106	0.00015†	2	0.12
Market			
54-79	0.0030†	30	1.00
80-84	0.0038†	38	1.27
85-92	0.0041†	41	1.37
93-106	0.0035†	35	1.17
Cull sows			
54-79	0.0027†	27	1.00
80-84	0.0056†	56	2.07
85-92	0.0052†	52	1.93
93-106	0.0061†	61	2.26

†significant at alpha=.05

Cull sows and market pigs were negatively impacted by an increase in HI. For every 10,000 market swine that go to slaughter in a week, our model suggests that we can expect to lose approximately 38, 41, and 35 market swine due to 'dead' condemnations at HI ranges 80-84F, 85-92F, and 93-106F, respectively. For every 10,000 cull sows that go to slaughter, we can expect to lose approximately 56, 52, and 61 at HI ranges 80-84F, 85-92F, and 93-106F, respectively. However, in roaster swine there was a decrease in condemnations at higher HI ranges. Our model predicts there will be approximately 17, 10, and two 'dead' condemnations for every 10,000 roaster swine that go to slaughter in a week at HI ranges 80-84F, 85-92F, and 93-106F, respectively.

Setting our baseline risk to be the weekly average temperatures ranging from 54-79F, the risk of condemnation (Table 2) is 1.41 times that of baseline within the 80-84F HI weekly average for roaster swine, 0.80 times within the 85-92F HI weekly average, and 0.12 times within 93-106F. For market swine the risk is 1.27 times greater in the 80-84F HI weekly average, 1.37 times greater with a weekly HI average within 85-92F, and 1.17 times greater than for those within 93-106F. In cull sows the risk is 2.07 times greater with a weekly HI average within 80-84F, 1.93 times greater within 85-92F weekly HI average, and 2.26 times greater for those within 93-106F. These effects were all significant ($p<0.05$).

Discussion

Pigs are susceptible to hyperthermia, leading to death during transportation in high temperatures (2). High humidity increases the likelihood of death since it reduces the ability of pigs to use evaporative cooling as a mechanism of heat loss (1). This retrospective observational study used the HI, which combines the effects of temperature and humidity, to predict the incidence and risk of death among swine in-transit and just prior to slaughter. As expected, market and cull sows experienced an increased incidence of 'dead' condemnations when the HI was above 80F and a doubling of incidence of 'dead' condemnations when the HI was above 93F for cull sows. Unexpectedly, roaster swine showed a different pattern, with decreasing incidence and risk at higher HI values. The smaller size of roaster pigs may make them more capable of dissipating heat and coping with a higher HI. They may be stocked less densely on transport trailers, giving them more space and less pig to pig contact, allowing them to stay cooler (4). Mitigation measures already in place may be more effective for roaster swine than larger swine types.

Limitations of this study include the inability to account for other factors related to death during transit such as length of the journey, the density of pigs on the trailer, genetics, and the use of mitigation measures such as water sprinklers and fans. Since we only had weekly condemnation data available, we can't make conclusions about the impact of individual days with high HI values. As a result of this study, weekly estimated HI values for slaughter establishments can be incorporated into the USDA, APHIS swine condemnation surveillance program so analysts can correlate signals for 'dead' condemnations with high HI values.

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