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Thomas C. Bridges
University of Kentucky, tom.bridges2@uky.edu

Larry W. Turner
University of Kentucky

Richard S. Gates
University of Kentucky

Douglas G. Overhults
University of Kentucky, doug.overhults@uky.edu

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Assessing the Benefits of Misting–Cooling Systems for Growing/Finishing Swine as Affected by Environment and Pig Placement Date

T. C. Bridges, L. W. Turner, R. S. Gates, D. G. Overhults

Abstract. *The NCPIG swine growth model was used to evaluate swine growth performance for Wilmington, North Carolina; Bardstown and Mayfield, Kentucky; and Oklahoma City, Oklahoma as influenced by the use of a misting–cooling system. Five pig placement dates (Julian days 106, 126, 146, 166, and 186) were evaluated for each location using 22 years of weather data (1978–1999). The use of a misting system, while quite variable, was found to be generally profitable, reducing the length of the time to reach market weight. As the placement date increased, the average return to misting ($/pig/year) decreased from $8.12 to $1.98 for Oklahoma City, from $6.00 to $1.16 for Wilmington, from $4.14 to $0.99 for Mayfield, and from $3.07 to $0.87 for Bardstown. Based on the prorated value of $1.39 per pig/per year for the cost of a misting system, probabilities for recovering the initial investment amount were determined for each pig placement date and location. These probabilities decreased as the pig placement date increased, except for Oklahoma City, which remained above 98% regardless of the date. For the locations other than Oklahoma City, the probabilities indicated that the earlier placement dates were more favorable for recovering the initial investment.*

Keywords. *Misting,Cooling,Growing–finishing,Swine.*

The growth performance of animals is often affected by extreme environmental conditions. In the case of swine, generally a cold environment will increase feed intake as the pig strives to maintain body temperature, while the warmer environments may reduce growth, increase body maintenance demands, and subject the animal to environmental stress. Confinement houses are widely used as a primary means of modifying the environment to improve conditions for swine growth. Environmental control in these structures is usually accomplished by natural or mechanical ventilation, installing building insulation for cold climates, and limited use of evaporative cooling for summertime conditions. Many swine producers in the United States have growing–finishing production facilities that are naturally ventilated with curtains on both sidewalls. During the summertime climates experienced in these areas, the inside temperature of these facilities often increases to levels that subject the hogs to heat stress that adversely effects pig growth, and few of these hog houses are equipped with any method of cooling. Use of evaporative cooling has the potential to reduce the inside temperatures in these facilities and minimize the heat stress the hogs are exposed to during the growth period.

Fundamental to the acquisition of any evaporative cooling system is the producer's desire to improve throughput of the production system while maintaining pig quality and improving profitability. One major concern is how the seasonal variability of weather influences the profitability of a cooling system and what pig placement date is most advantageous for potential gains that evaporative cooling may provide. A second consideration is the amount of investment capital the producer is willing to spend and the system's ability to recover this initial investment. The NC204 swine growth computer model (Bridges et al., 1992a, 1992b; Usry et al., 1992) has the capability to incorporate swine growth with feed intake, environment, and production economics to address the above concerns.

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The authors are **Thomas C. Bridges, ASAE Member Engineer,** Research Specialist, **Larry W. Turner, ASAE Member Engineer,** Associate Dean for Extension and Professor, **Richard S. Gates, ASAE Member Engineer,** Chairman and Professor,and **Douglas G. Overhults,** Extension Professor, Department of Biosystems and Agricultural Engineering, University of Kentucky, Lexington, Kentucky. **Corresponding author:** Tom Bridges, 128 Biosystems and Agricultural Engineering Department, University of Kentucky, Lexington, KY 40456–0276; phone: 859–257–3000 ext. 209; fax: 859–257–5671; e–mail: tbridges@bae.uky.edu.

Background

Several researchers have shown that high temperatures adversely affect swine growth and feed intake. In a 21–day study of the effects of warm diurnal temperatures, Lopez et al. (1991) found that pigs raised in a hot environment (22.5°C to 35°C) gained weight at a 16.3% lower rate, and feed intake was 10.9% less compared to pigs raised under a constant temperature of 20°C. Morrison et al. (1975) also observed a reduced growth rate for finishing pigs under a high temperature of 27.5°C compared to those at a thermoneutral temperature (20°C). Roller et al. (1967) and Roller and Goldman (1969) found that daily feed consumption, average daily gain, and reproductive performance were significantly reduced as dry bulb and dew point temperature increased.

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The results of these studies clearly indicate that some form of cooling would be beneficial in reducing animal heat stress under warm climates while improving rate of gain and feed conversion.

Evaporative pad cooling has been the most popular method used to cool livestock facilities. However, pad cooling requires significant capital investment. Snout cooling has been used primarily on sows (Raap et al., 1988). In Kentucky, neither of these types of cooling is prevalently found in growing–finishing swine buildings; most cooling done by producers in the state for growing–finishing pigs is direct sprinkling of the animals. Evaporative misting has been shown to be a viable alternative, effective in poultry houses in the southeastern United States and elsewhere. A misting system sprays small water droplets into the air that reduces the surrounding air temperature in the confinement structure as evaporation takes place. In comparison, sprinkling uses a larger droplet size which directly wets the animal's skin or hair coat, and then cooling results from evaporation of the water. Evaporative misting systems are lower in efficiency compared to the conventional pad systems (Timmons and Baughman, 1983; Bottcher et al., 1991) but have a substantially lower initial investment. Gates et al. (1991a, 1991b) analyzed misting systems for growing–finishing hogs and found these systems to compare favorably with evaporative pad cooling when minimizing the interior temperature–humidity index (THI). Improvements in poultry production related to a reduced THI in the confinement structure have been used to locate regions in the southeast United States suitable for a particular housing design (Gates et al., 1995).

The decision to use environmental modification such as misting in any housing type is generally based on increased economic return to the producer. These returns may be quite different for individual years depending on the existing environment and the current economics of pig production. Bridges et al. (1992c) evaluated returns to misting for growing–finishing swine [44 to 100 kg (97 to 220 lb)] using 42 years of weather data in central Kentucky and found feed savings to range from $800 to $2964 for the coolest to the warmest period for a 600–pig facility. Researchers working with other animal species have also addressed this aspect using stochastic simulations of weather variation to determine the economic benefits of evaporative cooling. Gates and Timmons (1988a) used a stochastic weather model (Timmons and Gates, 1988) to generate 200–year simulations at different geographic locations and found that using evaporative cooling for laying hens could provide significant production benefits in all regions. A similar analysis for broilers (Timmons and Gates, 1989a) indicated that evaporative cooling increased production benefits for mean daily temperatures higher than 25°C. Gates and Timmons (1988b) developed a technique for evaluating stochastic results, and found a higher potential economic benefit for evaporative cooling compared to a conventional analysis based on mean design temperatures. While these studies indicate that a misting–cooling system would be beneficial in terms of economics, the actual returns in an individual production situation are a function of several variables that are difficult for the producer to evaluate. Software to assist in this type of analysis is available for poultry systems (Timmons and Gates, 1989b) but not for swine.

NC–204 Swine Growth Model

For the economic evaluation of a swine production situation, it is necessary to estimate the growth performance of growing–finishing pigs under the conditions imposed by the producer. This growth evaluation was accomplished using the swine growth model (NCPIG) developed by the North Central Regional Swine Modeling Committee (NC–204). This model (Bridges et al., 1992a, 1992b; Usry et al., 1992) is physiologically based and simulates the interactions of feed intake, nutrient digestion, body maintenance, tissue accretion, and response to environment for an individual animal over time. NCPIG uses small time steps (0.1 h) to simulate growth and determines the physiological progress of a single animal by accumulating the empty body constituents of protein, fat, water, and minerals at the end of each chronological day. Growth curves for each body component are used to determine the animal's daily growth rate.

As the model simulates growth, it also performs a heat balance for each time step using the metabolic heat production from the previous time step. Metabolic heat production of the simulated animal includes that heat production related to body maintenance, lean tissue and excess fat growth, fiber digestion, and voluntary activity. This heat production can vary over time depending on the metabolic activity of the animal and is partitioned into sensible and latent components. Simplifying assumptions concerning the animal and its environment are made as follows: the pig is standing (huddling is not considered); solar effects on the animal are ignored; no radiant heater is in the structure; and any cooling of the animals by splashing of water or urine is not considered. For further discussion of the heat transfer aspects used in NCPIG and the manner in which heat stress is simulated, the reader is referred to Usry et al. (1992) and Bridges et al. (1992c).

One goal in the development of the NC–204 model is to provide producers, researchers, extension and agribusiness personnel with a management tool to be used as an aid in decision making. While the model has been extensively tested against research data, it was deemed necessary to compare model values with data from a commercial operation. As a part of a National Pork Producers Council educational program in the fall of 1995, the research and extension team at the University of Kentucky was connected with a commercial producer to test the NCPIG model against on–farm growth data. The Phillip Lyvers swine operation located near Loretto, Kentucky participates in a marketing network of some 15 to 30 producers. The commercial facility consists of a 336–pig naturally ventilated facility with curtain sides using a thermostatically controlled sprinkler system and partially slatted pens. Two grow–finish periods [20 to 107 kg (44 to 236 lb)] from the Lyvers operation were used in growth comparisons with NCPIG (Turner et al., 1998). The model was calibrated against one group of animals ('white' barrows) and simulations were conducted comparing days on feed, final slaughter weight, average daily feed intake and weight gain, backfat thickness, and the fat–free–lean index (FFLI) for the second group of pigs ('red' barrows). Generally, production data from the model was found to be within ±5% of the observed data. Once the model was successfully calibrated to the production data, it was then used to evaluate the economics of using a misting–cooling system in a commercial facility (Bridges et al., 1998). The growth of the barrows was simulated using two weather years from Bardstown, Kentucky (1995 and 1983) and two different dates when pigs were started in the facility. Bardstown, Kentucky is located approximately 16 km (10 miles) northeast of the Lyvers swine operation. The simulation results generally showed that the use of a misting–cooling system reduced the time of growth to market and produced a pig with less backfat. Bridges et al. (2000) later showed using 21 years (1978–1998) of daily weather data for Bardstown and Mayfield, Kentucky, that the economic benefit of the misting–cooling system was highly dependent on the weather year and date the pigs were started in the facility. While it appeared from that study that misting–cooling was beneficial to swine producers in those Kentucky locations, questions were raised as to the profitability of such a system and its ability to recover the initial investment for other swine production areas in the United States.

Procedure

In order to determine the effect of different weather years on the profitability of a misting–cooling system for swine, pig growth was simulated for the locations of Wilmington, North Carolina and Oklahoma City, Oklahoma and compared to the earlier results found for Bardstown and Mayfield, Kentucky (Bridges et al., 2000). North Carolina and Oklahoma represent two of the larger swine producing states in the United States, and Wilmington and Oklahoma City are located near these production areas. In terms of weather, Wilmington is representative of the warm humid southeast region of the United States and Oklahoma City (approximately 1,850 km (1,150 miles) west and 1° north of Wilmington in latitude) has an equally warm climate that would be characterized as less humid than Wilmington. Bardstown, Kentucky is approximately 64 km (40 miles) south of Louisville, Kentucky in the central part of the state and Mayfield is located on the far western portion of the state approximately 280 km (174 miles) southwest of Bardstown. Both Kentucky locations are representative swine production locales and are approximately 2 to 3° north in latitude, equidistant from the other cities in this study. Their environment could also be characterized as generally humid, but slightly cooler than either Wilmington or Oklahoma City.

The pig growth simulations included a medium to high lean growth barrow that was used in the earlier model comparisons (Turner et al., 1998, Bridges et al., 1998). An option is available in the NC–204 model to specify an environment that includes misting in a naturally ventilated curtain–sided facility that is a popular option with swine producers. The model strategy used for determining inside conditions in this type of facility when the misting option is used is detailed in Bridges et al. (1992c), and the set point at which misting would begin in the facility is 25°C (77°F). Benefits to misting–cooling were determined by conducting simulations with and without misting for the same facility type and identical weather. The simulations were begun with an initial pig weight of 24.3 kg (53.6 lb) and were terminated on the day the simulated animal reached or exceeded a target weight of 107.5 kg (237 lb). It should be noted that the producer in the earlier comparisons used direct sprinkling as opposed to misting for a cooling method, and the term misting–cooling in this article is synonymous with sprinkling.

Pig Placement Date

The misting comparisons for the commercial facility (Bridges et al., 1998) were conducted when the barrows entered or placed in the grow–finish facility on 5 July 1999 (Julian day 186). To evaluate the effect of pig placement date, four dates, 20 days apart, preceding 5 July were chosen. These dates corresponded to 15 June (Julian day 166), 26 May (Julian day 146), 6 May (Julian day 126), and 16 April (Julian day 106) and were used as beginning times for additional simulation analyses at each location.

Economics

Most management decisions in any agricultural operation must include the economics associated with the particular production enterprise being examined. In swine production, the producer must identify several cost variables to determine the profit (loss) with a group of pigs. This analysis involves pigs in the growing–finishing stage of production beginning at approximately 20 kg (44 lb) and ending with live slaughter weights in the 105– to 110–kg (231– to 242–lb) range. During development, it was desirable that the NCPIG model be used as a management tool; therefore the economic input information was limited to values that swine producers could readily supply pertaining to their particular situation. Identified fixed costs included the initial investment for getting the pig into the finishing facility, a fixed cost of the facility ($/pig), and any miscellaneous fixed costs ($/pig) that might be incurred such as a misting–cooling system. The fixed cost of the facility was based on the total investment cost of the facility and associated equipment (feeders, fans, manure loaders, etc.), and assumed three groups of pigs are finished in the structure in a given year. Variable cost estimates included an interest charge for the initial pig investment (%), a labor charge (cents/pig/day), and the feed cost ($/kg) for each ration. The operating cost ($/pig), veterinary cost ($/pig) and marketing cost ($/pig), were based on budget estimates for grow–finish operations in Kentucky (Trimble et al., 1993). Net return for each pig was based on the producer's estimate of the market value of the pig carcass ($/kg). Table 1 shows the fixed and variable costs used in this analysis. These costs are representative values for existing swine production facilities in central Kentucky and may vary somewhat with each individual producer. The carcass value was based on an average price received by Kentucky producers in 1995.

Table 1. Swine production cost variables used in this analysis.

Fixed Production Costs ($/pig)		Variable Production Costs	
Initial pig value in facility	20.00	Interest rate	10.0%
Facility w/o misting–cooling	5.00	Labor	3.0 cents/pig–day
Facility w misting–cooling	5.30	Operating cost	$1.00/ pig
		Veterinary cost	$3.00/ pig
		Marketing cost	$2.00/ pig
Feed Costs	$/kg ($/ton)	Carcass Sale Price $/kg ($/cwt)	
Ration 1	0.15 (136.3/)	Base value	1.1023 ($50)
Ration 2	0.143 (129.5)		

Feed

The Lyvers 'red' barrow group used for the comparison study was fed two corn–soybean grow–finish diets with supplemental lysine as detailed by Turner et al. (1998). The first diet (ration #1) was fed in the 20– to 60–kg (44– to 132–lb) weight range and the second diet (ration #2) from 60 kg (132 lb) to market weight and the same feeding regime was retained for this study. Each of the simulated diets in the NCPIG model used the same composition as the 'red' barrow rations and the ration costs used for this analysis are shown in table 1. The respective crude protein and digestible energy values were 16.9% and 15.4 MJ/kg (1668.7 kcal/lb) for ration 1 and 15.3% and 15.36 MJ/kg (1664.4 kcal/lb) for ration 2.

Results

Average values for the days on feed with and without misting for the simulated pig and average net return to misting for 22 years are shown for five pig placement dates at Wilmington, North Carolina; Bardstown and Mayfield, Kentucky; and Oklahoma City, Oklahoma in table 2. Generally, for the four locations considered in this study, the earlier Julian dates for pigs entering the facility were more beneficial in reducing the days on feed and increasing profitability of the misting system. On average, the largest reductions in the simulated growth periods were found for Oklahoma City, followed by Wilmington, and then Mayfield and Bardstown (table 2).

The yearly net return ($/pig/year) to misting at each location was quite variable for the 22 years as shown by figures 1 through 4. The figures show that the earlier pig placement date (Julian day 106) returned substantially more profit to misting than when the pigs were begun in the grow/finish facility on Julian day 186. Generally the yearly returns to misting for the intermediate placement dates (Julian days 166,146,126) were between those shown in Figures 1 through 4 and these results were not included in the figures for clarity. Table 3 presents the maximum, minimum, and average returns to misting for the five placement dates by location. The average yearly return ($/pig–year) to misting ranged from $8.12 to $1.98 for Oklahoma City, from $6.00 to $1.16 for Wilmington, from $4.14 to $0.99 for Mayfield and from $3.07 to $0.87 for Bardstown. It can be seen from the figures and the values in table 3 that misting–cooling was more profitable for Oklahoma City and Wilmington than either Kentucky site for the 22–year period. The values shown in table 3 and figures 1 through 4 illustrate the variability in production that the producer is faced with due to the weather and demonstrate the risk involved in investing in an agricultural enterprise.

One purpose for using a stochastic analysis is to evaluate various levels of risk that the producer may expect when implementing a misting system. The deterministic growth model combined with several years of weather has determined responses of the animal subjected to different growing conditions much as would be experienced in the real housing situation. If the producer chooses to invest in a misting system, there is a certain amount of risk in recovering the investment cost over the expected life of the misting system. Gates and Timmons (1988a) presented a method for analyzing this type of risk using a computed t–statistic (t^*) to determine the probability that the average return over the life of the system, $\bar{d}$, will be less than some threshold cost value, c. The risk probability is defined as follows:

$$P(\bar{d} < c \mid \mu,\sigma) = P(t_{(n-1)} < t^*) \quad (1)$$

and the value of t^* is found by:

$$t^* = \frac{(c-\mu)}{s/(n-1)^{(1/2)}} \quad (2)$$

Table 2. The average length of the simulated growth period (days) with and without misting for the 22 years of record by pig placement date and the four locations in this study.

Pig Placement Date (Julian Day)	Avg. Growth Period w/o Misting (Days)	Avg. Growth Period with Misting (Days)	Avg. Reduction in Growth Period (Days)
Wilmington, N.C.			
106	159.6	125.9	33.7
126	153.5	130.6	22.9
146	144.7	127.0	17.7
166	134.1	119.9	14.2
186	122.8	111.7	11.1
Bardstown, Ky.			
106	118.4	102.0	16.4
126	121.7	106.5	15.2
146	118.9	106.3	12.6
166	112.8	103.1	9.7
186	105.5	98.2	7.3
Mayfield, Ky.			
106	134.1	111.8	22.3
126	135.8	117.3	18.5
146	129.4	115.1	14.3
166	120.6	109.7	10.9
186	111.4	102.9	8.5
Oklahoma City, Okla.			
106	151.2	108.0	43.2
126	147.4	113.6	33.8
146	139.4	113.7	25.7
166	129.5	108.6	20.9
186	118.3	102.0	16.3

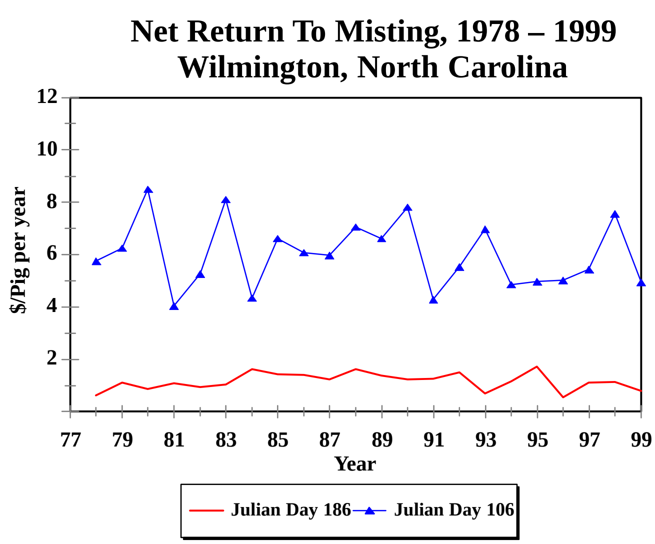

Figure 1. Net return to misting ($/pig/year) for Wilmington, North Carolina, 1978 through 1999 for pigs entering the facility on Julian days of 106 and 186.

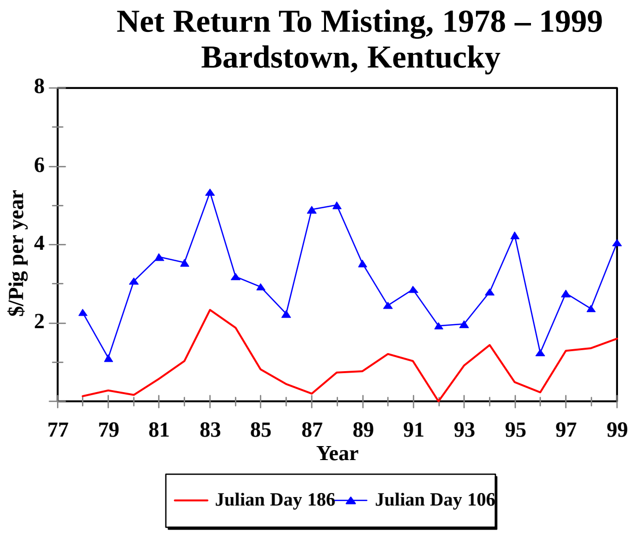

Figure 2. Net return to misting ($/pig/year) for Bardstown, Kentucky, 1978 through 1999 for pigs entering the facility on Julian days of 106 and 186.

where

- t^* = the computed t–statistic with n–1 degrees of freedom
- $\bar{d}$ = the average annual return to misting per year over the life of the system ($)
- c = the threshold investment cost ($/y)
- μ = the population mean or in this case the average return to misting per year for the 22 years of record for one pig placement date at either location ($)
- s = the standard deviation of the population mean
- n = the degrees of freedom based on the life of the misting system

For example, assume that the investment cost for a misting system is $5.00 per pig space with a 7–year life and the rate for interest and taxes is 10% per annum over the life of system. This yields a total investment of $9.74 per pig space and necessitates a return of $1.39 per year if the cost per space is prorated over the life of the system. Operating costs were not considered in this study. If the pigs were started in the grow/finish facility on 26 May (Julian day 146) at Bardstown, from equation 2 the threshold cost (c) = $1.39, μ = $2.00 per pig, and s = 0.798 (table 3), n = 7, the life of the misting system, then t^* = –1.87. For a one–tailed test, the area under the probability curve from t^* to minus infinity, is approximately 0.055. This represents the probability (α) or risk that $\bar{d}$ will be less than the threshold cost, c. The probability of success or that $\bar{d}$ will exceed the threshold investment cost, c, then, is 1 – α or approximately 0.945 or a 94.5% probability that the return to misting will be at least $1.39 per pig per year for Bardstown when placing the pigs in the facility on 26 May (table 4).

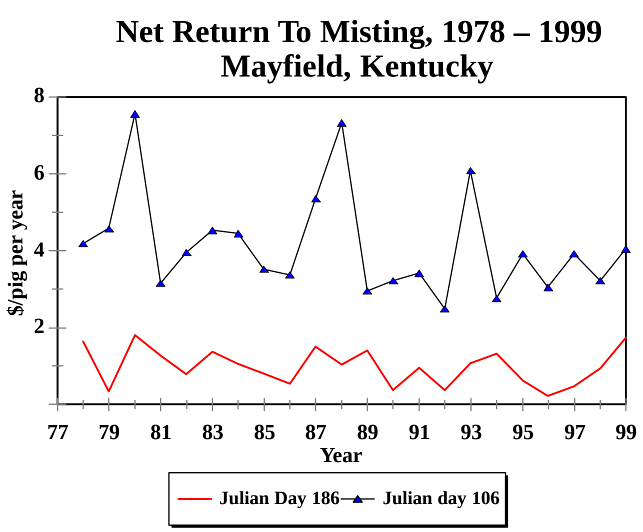

Figure 3. Net return to misting ($/pig/year) for Mayfield, Kentucky, 1978 through 1999 for pigs entering the facility on Julian days of 106 and 186.

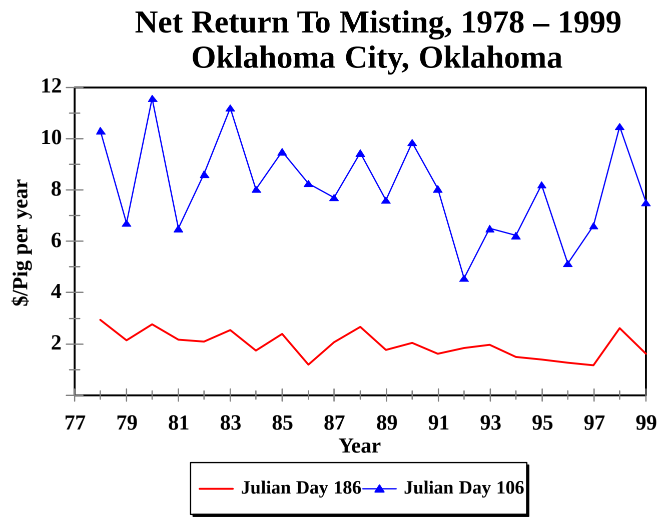

Figure 4. Net return to misting ($/pig/year) for Oklahoma City, Oklahoma, 1978 through 1999 for pigs entering the facility on Julian days of 106 and 186.

Table 3. Maximum, minimum, average, and standard deviation of the return to misting ($/pig/year) by pig placement date for the 22 years of record for the four locations in this study.

Pig Placement Date (Julian Day)	Maximum Return ($/pig/year)	Minimum Return ($/pig/year)	Avg. Return ($/pig/year)	Std. Deviation ($/pig/year)
Wilmington, N.C.				
106	8.50	4.04	6.00	1.252
126	5.69	2.24	3.42	0.827
146	3.14	1.01	2.14	0.596
166	2.37	0.79	1.53	0.429
186	1.72	0.56	1.16	0.319
Bardstown, Ky.				
106	5.35	1.11	3.07	1.144
126	6.48	0.60	2.56	1.151
146	3.76	0.39	2.00	0.798
166	2.70	0.23	1.24	0.686
186	2.34	0.02	0.87	0.618
Mayfield, Ky.				
106	7.56	2.49	4.14	1.363
126	5.36	1.20	3.05	0.942
146	3.53	0.72	1.90	0.737
166	2.23	0.19	1.25	0.534
186	1.80	0.22	0.99	0.484
Oklahoma City, Okla.				
106	11.58	4.57	8.12	1.837
126	7.45	3.03	5.42	1.112
146	5.30	1.59	3.44	0.832
166	3.76	1.24	2.39	0.613
186	2.95	1.17	1.98	0.514

Table 4. The probability of a net return to misting of at least $1.39 per pig per year for the four locations in this study by pig placement date.

	Pig Placement Date (Julian Date)				
	16 April (106)	6 May (126)	26 May (146)	15 June (166)	5 July (186)
Location	Probability (%)				
Wilmington, N.C.	99.9	99.9	98.9	77.3	6.4
Bardstown, Ky.	99.4	97.6	94.5	30.6	4.2
Mayfield, Ky.	99.8	99.7	92.9	27.2	4.5
Oklahoma City, Okla.	99.9	99.9	99.9	99.6	98.4

Table 4 presents the probabilities for a net return to misting of $1.39 per pig per year required to pay for such a system over its life for each of the locations by pig placement date. It can be seen from the table that the earlier placement dates (Julian days 106, 126, 146) have a high probability of making the threshold cost while the later dates have a much lower likelihood of achieving this value except for Oklahoma City. The probabilities in Table 4 illustrate that the value of a misting system, while still beneficial to the pigs at the later dates, is more profitable when the animals are placed in the facility in April and May. When the animals are begun in April and May they will grow to be larger when the heat is most likely to be the greatest (June, July, August) and are in greater need of a cooler environment to continue growth and reduce stress levels.

SUMMARY

The returns shown in this article make the use of a misting system with pigs look very favorable, but should be viewed as the best possible situation for misting in a growing–finishing facility. This analysis used 22 years of available weather and as shown by Gates and Timmons (1988b), longer periods of weather records are desirable. It was also assumed in this analysis that the curtain controller supplies adequate ventilation, and this may not always be the case in actual facilities. The temperature reductions simulated in the facility are a function of whether the natural ventilation combined with the efficiency of misting can achieve an inside relative humidity of 80%. In actuality, there will be periods during the growth cycle when natural ventilation with evaporative misting will not be sufficient to reach this value of humidity. Solar loading (not considered in this analysis) may lower the expected temperature reductions due to misting. In facilities where flush systems are used, inside humidities will be higher. Further work should be done to determine specific misting rates necessary and evaluate the benefits of misting with respect to pig performance in a growing–finishing facility of this type.

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