Agricultural Engineering Extension Publications

Biosystems and Agricultural Engineering

12-2003

Assessing the Benefits of Misting-Cooling Systems for Growing-Finishing Swine in Kentucky as Affected by Environment and Pig Placement Date

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

R. S. Gates
University of Kentucky

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

Larry W. Turner
University of Kentucky

UK COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY—COLLEGE OF AGRICULTURE

Assessing the Benefits of Misting-Cooling Systems for Growing-Finishing Swine in Kentucky as Affected by Environment and Pig Placement Date

T.C. Bridges, R.S. Gates, D.G. Overhults, and L.W. Turner[1]

Introduction

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 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 the growth of swine. Environment in these structures is usually controlled by natural or mechanical ventilation and by insulation for cold climates and limited use of evaporative cooling for summertime conditions.

Most swine producers in Kentucky have growing-finishing production facilities that are naturally ventilated with curtains on both sidewalls. During the summer, the inside temperature of these facilities often reaches levels that can cause heat stress for the animals and adversely affect pig growth. Few hog houses are equipped with any method of cooling, yet the use of evaporative cooling may reduce the inside temperatures in these facilities and minimize the heat stress on swine.

This publication illustrates the potential economic benefits of using a misting-cooling system and the capability of the system to recover the producer's initial investment as affected by the starting date of the pigs in the growing-finishing facility (pig placement date) and the seasonal variation of weather for ten locations in Kentucky.

Considerations in Selecting a Swine Misting-Cooling System

Two methods for evaporative cooling of swine are most prevalent in Kentucky: evaporative misting and direct sprinkling of the pigs. An evaporative misting system sprays small water droplets into the air, thereby reducing the surrounding air temperature in the confinement structure as evaporation takes place. Thus, the animals are exposed to a cooler air temperature and reduced heat stress. Direct sprinkling uses a larger water droplet size that directly wets the animal's skin or hair coat; cooling of the animal thus results from evaporation of the water. In Kentucky, most cooling done by swine producers is direct sprinkling of the animals. The two systems are comparable in reducing the effects of heat stress during pig growth, and the results shown in this publication may be applied both to evaporative misting and direct sprinkling systems.

Evaporative misting has been shown to be a viable alternative to other cooling systems, such as the conventional pad cooling that has been effective in poultry houses in the southeastern United States and elsewhere. In contrast to the conventional pad cooling systems, evaporative misting compares favorably when minimizing the interior temperature-humidity index (THI). Also, it is somewhat lower in efficiency and has a substantially lower initial investment cost.

One consideration for using a misting-cooling system is a desire to reduce the impact of heat stress on the pig and improve the animal's growth rate in the growing-finishing facility. An improved growth rate means fewer days on feed, an earlier market date for the pigs, and a better quality product, which in turn should result in increased profitability for the producer. An additional benefit from earlier market dates for the pigs is increased flexibility in the use of the growing-finishing facility. However, as this publication will show, animal growth rate and the profitability of a misting-cooling system varies from year to year due to the seasonal variation in weather and also by time of year the pigs are started in the growing-finishing facility (pig placement date).

Profit in any agricultural enterprise is important, and it is necessary to weigh the benefits and costs of changes to the production facility. A second consideration in using a misting-cooling system is the amount of investment capital the producer has available for installation and the potential of the cooling system in recovering this initial investment with expected profits. A misting-cooling system is most beneficial in reducing the impact of heat stress for the animals when ambient temperatures are higher and the pigs are larger in size (50 kg plus). In Kentucky, the higher temperatures generally occur in the summer months (June, July, and August), so the time of year when the animals are started in the facility becomes important in terms of profit potential for the cooling system.

This publication reports the work of studies done at the University of Kentucky (Bridges et al., 2000, Bridges et al., 2003) and details the effect of the yearly variation in weather and the time of year the pigs are started in the growing-finishing facility on potential benefits of a growing-finishing swine facility with a misting-cooling system for various locations in Kentucky.

[1] *The authors are, respectively, Research Specialist, Chairman and Professor, Extension Professor, and Associate Dean for Extension and Professor in the Department of Biosystems and Agricultural Engineering, University of Kentucky, Lexington, Kentucky.*

NC-204 Swine Growth Model

The decision to use environmental modification such as a misting-cooling system in a growing-finishing facility is generally based on increased economic return to the producer. These returns may be quite different for individual years depending on the growth rate of the pigs, the existing environmental conditions, and the current economics of pig production. In order to determine the profitability of a misting-cooling system, it was necessary to compare swine animal growth with and without such a system for a given set of production variables and environmental conditions. This was accomplished using the swine growth simulation model (NCPIG) developed by the North Central Regional Swine Modeling Committee (NC-204) at the University of Kentucky.

The NCPIG swine model determines the growth of a medium to high lean growth genotype by simulating the interactions of feed intake, nutrient digestion, body maintenance, tissue accretion, and response to environment for an individual animal over time. The NCPIG model can be used as a management tool and allows the individual user to specify various diets, environments, genetics, and economic variables and determines changes in pig growth, body composition, feed intake and efficiency, waste composition, and economic profitability.

One of the environmental options in the model includes the use of daily maximum and minimum temperature and humidity values for a given location, which allows for the variation of weather during the growth period to be introduced. The housing option in the model considers a naturally ventilated facility with curtain sides, partially slatted pens, and an option to include a misting-cooling system. NCPIG has been extensively tested against research data (Bridges et al., 1992a, 1992b; Usry et al., 1992) and has been compared against production data from a commercial operation in Kentucky (Turner et al., 1998, Bridges et al., 1998). Generally in the commercial test, values for average daily gain, feed intake, and feed conversion from the NCPIG model were found to be within $\pm$5% of the observed data.

Swine Growth Comparisons with and without Misting

For the study in this publication, the NCPIG swine growth model was used to simulate pig growth for ten locations across the state of Kentucky. Most swine production occurs in the western portion of Kentucky, and the locations chosen in this study were representative of this area as well as other potential swine production locales in the state. Twenty-two years of weather data (1978-1999) and five pig placement dates were chosen to determine the effect of different weather years and starting dates in the growing-finishing facility on the profitability of a misting-cooling system for swine. These ten locations, listed in Table 1, range from Mayfield in the west to Grayson in the east and from Cumberland Gap and Somerset in the south to Williamstown in the north. The selected pig placement dates are 20 days apart and are April 16 (Julian day 106), May 6 (Julian day 126), May 26 (Julian day 146), June 15 (Julian day 166), and July 5 (Julian day 186).

Table 1. Alphabetical listing of Kentucky stations in this study.

Station
Bardstown
Cumberland Gap
Glasgow
Grayson
Henderson
Lexington (Spindletop)
Mayfield
Quicksand
Somerset
Williamstown

To determine the profitability of a misting-cooling system for each location in the study, two pig growth simulations were conducted using weather data for a given year beginning on a given pig placement date. One simulation assumed the growing-finishing facility contained a misting-cooling system, and one did not. The net return to the producer ($/pig) was determined for both simulations, and the profitability for the facility having a cooling system was determined to be the difference in the two results. This procedure was repeated for each weather year and each pig placement date for a total of 220 simulations at each location. The pig genotype used in the growth simulations is considered as a medium to high lean growth barrow, and each simulation was begun with an initial pig weight of 24.3 kg (53.6 lb) and terminated on the day the simulated animal reached or exceeded a market weight of 107.5 kg (237 lb).

The fixed and variable costs used in this analysis are expressed on a per pig basis and are detailed in Table 2. These values are representative costs for existing swine production facilities in Central Kentucky (Trimble, et al., 1993) and remained constant for each growth simulation. However, the values in Table 2 may vary somewhat with each individual producer. The net return to the producer for each simulation was calculated based on the final simulated weight and carcass sale price (Table 2). The carcass price for this analysis reflects an average price received by Kentucky producers in 1995.

The facility option specified for each simulation in the swine growth model is the naturally ventilated curtain-sided facility that is a popular option with swine producers in Kentucky. The model strategy used for determining inside conditions for a facility of this type with a misting-cooling system is detailed in Bridges et al. (1992c), and the set point at which misting begins in each simulation is 25°C (77°F).

For each growing-finishing simulation in this study, the simulated pig was fed two corn-soybean growing-finishing diets with supplemental lysine as detailed by Turner et al. (1998). The first diet (ration No. 1) was fed until the simulated pig reached 60 kg (132 lb), and the second diet (ration No. 2) was fed from 60 kg (132 lb) to market weight of 107.5 kg (237 lb). The respective crude protein and digestible energy values were 16.9% and 15.4 MJ/kg (1668.7 kcal/lb) for ration No. 1 and 15.3% and 15.36 MJ/kg (1664.4 kcal/lb) for ration No. 2. The respective ration costs are listed in Table 2.

Table 2. Swine production cost variables used in this analysis.

Fixed Production Costs			Variable Production Costs	
Initial pig value in facility		$20.00/pig	Interest rate	10.0%
Facility w/o misting-cooling		$5.00/pig	Labor	$0.03/pig/day
Facility w/misting-cooling		$5.30/pig	Operating cost	$1.00/pig
			Veterinary cost	$3.00/pig
			Marketing cost	$2.00/pig
Feed Costs			**Carcass Sale Price**	
Ration No. 1	$0.15/kg	($136.3/ton)	Base value	$1.1023/kg ($50/cwt)
Ration No. 2	$0.143/kg	($129.5/ton)		

Reductions in the Simulated Growing-Finishing Period with a Misting-Cooling System

For the results shown in this analysis, the term misting-cooling system may refer to either evaporative misting or direct sprinkling of the pigs. Using 22 years of weather data, the NCPIG model simulated responses of the animal much as would be experienced in the real housing situation. The results show that the length of the simulated growing-finishing period was quite variable due to different weather conditions for the 22 years at each location. Figure 1 illustrates an example of the variability of the growing-finishing period for one location (Henderson, Kentucky) and one placement date (May 6, Julian day 126) with and without a misting-cooling system. Figure 1 shows that, with no cooling, the growth period ranged from a maximum of 148 days in 1980 to a minimum of 121 days in 1992. This compares with a maximum-minimum range of 125 days in 1995 to 103 days in 1984 for a facility in which the pigs had a cooling system available. Figure 1 also illustrates that when using a cooling system, the yearly reduction in the length of the growth period for a given location is dependent on the weather conditions in the growing season. Table 3 shows that on average for the 22 years studied, pigs beginning in the facility on May 6 (Julian day 126) at Henderson would require an average growth period of 131 days with no misting compared to an average of 114.1 days for a facility with misting. This is an average reduction of approximately 17 days in the growing-finishing period for a facility with a misting-cooling system and a significant payback for fewer days on feed and an earlier market date.

Figure 1. The simulated growing-finishing period with and without misting for pigs placed in the growing-finishing facility on May 6 (Julian day 126) from 1978 through 1999 at the Henderson, Kentucky, location.

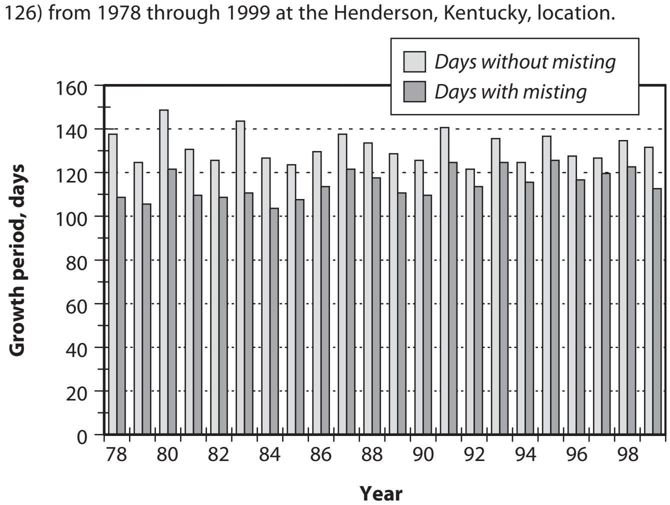


Table 3 presents the 22-year average reductions in the length of the simulated growing-finishing period by location for the five placement dates in this study. On average, the largest reductions for a facility with a cooling system were found for Mayfield, Glasgow, and Henderson for the April 16 placement date, and the smallest average declines were found for Grayson and Cumberland Gap for the July 5 placement date. Generally, the averages in Table 3 indicate that facilities with a cooling system are beneficial in increasing the pig growth rate, i.e., reducing the time for the pigs to market, but the reduction in time for having a cooling system generally is less for a given location as the placement date occurs later in the year. In a nutshell, the later the placement date, the smaller the benefit.

Profitability of Misting-Cooling Systems

To determine the profitability of a growing-finishing facility with a misting-cooling system, the yearly net return ($/pig/year) of the simulations with and without cooling were compared at each location and for each placement date. The results reflected the unpredictability of local weather and were rather variable for the 22 years. Figure 2 demonstrates the yearly variability of the return to misting for one location (Bardstown, Kentucky) and two placement dates (July 5, Julian day 186 and April 16, Julian day 106). The figure shows that the earlier pig placement date (Julian day 106) returned substantially more profit to a facility with cooling on a yearly basis than when the simulated pigs were begun in the growing-finishing facility on Julian day 186. For the April 16 placement date at Bardstown, the maximum yearly profit was $5.35 in 1983, and the minimum was $1.11 in 1996. These values compare to a maximum net return of $2.34 in 1983 and a minimum of $0.02 in 1992 for the July 5 placement date. Generally the yearly returns due to misting for the intermediate placement dates (Julian days 166, 146, and 126) were within the range shown in Figure 2, and for clarity these were not included in the figures. Figure 2 illustrates the randomness in production due to weather variability and demonstrates the risk that faces the producer when investing in an agricultural enterprise.

Table 4 presents the maximum, minimum, average net return, and the standard deviation of the return for using a misting-cooling system by placement date for the 22 years of record and the ten locations in this study. The average return ($/pig/year) due to misting ranged from a maximum of $4.16 for Glasgow starting on April 16 to a minimum of $0.41 for Grayson.

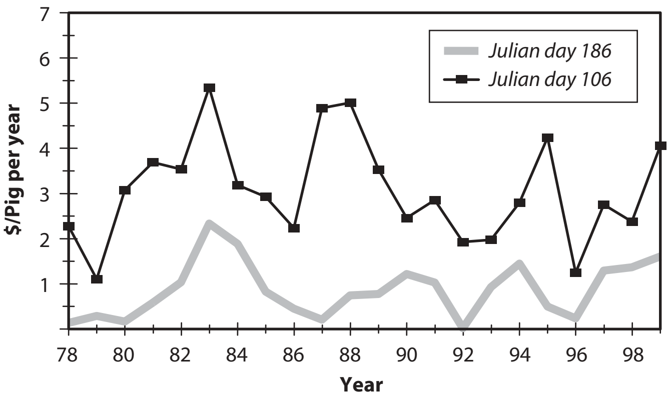
Table 3. The average length of the simulated growth period and standard deviation (days) with and without misting for the 22 years of record (1978-1999) by pig placement date and the ten locations in this study.

Pig Placement Date (Julian Day)	Average Growth Period w/o Misting (Days)	Standard Deviation (Days)	Average Growth Period with Misting (Days)	Standard Deviation (Days)	Reduction in Growth Period with Misting	Average Growth Period w/o Misting (Days)	Standard Deviation (Days)	Average Growth Period with Misting (Days)	Standard Deviation (Days)	Reduction in Growth Period with Misting
	Bardstown, Kentucky					**Lexington, Kentucky**				
106	118.4	9.0	102.0	7.2	16.4	115.9	9.6	100.1	4.4	15.8
126	121.7	8.1	106.5	8.1	15.2	120.4	7.4	104.9	4.7	15.5
146	118.9	6.5	106.3	7.7	12.6	118.3	5.8	105.4	4.0	12.9
166	112.8	6.3	103.1	6.8	9.7	111.9	5.2	102.2	3.7	9.7
186	105.5	5.1	98.2	6.1	7.3	104.9	4.2	97.6	3.2	7.3
	Cumberland Gap, Kentucky					**Mayfield, Kentucky**				
106	112.4	7.5	100.9	5.7	11.5	134.1	8.8	111.9	7.0	22.2
126	117.7	6.3	106.0	6.4	11.7	135.8	6.5	117.3	6.3	18.5
146	116.9	5.3	106.6	5.7	10.3	129.4	5.8	115.1	4.8	14.3
166	111.0	4.3	103.4	4.7	7.6	120.6	5.2	109.7	4.3	10.9
186	104.1	3.7	98.7	4.1	5.4	111.4	4.4	102.9	3.5	8.5
	Glasgow, Kentucky					**Quicksand, Kentucky**				
106	126.5	10.5	104.7	6.3	21.8	114.3	9.8	102.3	7.1	12.0
126	127.9	8.7	109.0	6.6	18.9	119.6	8.4	108.1	7.8	11.5
146	123.2	6.5	108.4	5.4	14.8	118.6	5.9	108.9	7.1	9.7
166	115.6	5.6	104.0	4.4	11.6	113.2	5.4	106.1	6.3	7.1
186	107.2	4.5	98.9	3.4	8.3	106.4	4.7	101.2	5.5	5.2
	Grayson, Kentucky					**Somerset, Kentucky**				
106	106.4	4.9	98.7	3.5	7.5	111.9	6.4	96.3	3.7	15.6
126	111.5	5.0	103.4	3.5	8.1	115.3	6.5	99.7	4.5	15.6
146	111.3	4.2	104.7	4.4	6.6	113.3	5.7	99.9	3.1	13.4
166	107.5	3.8	102.2	4.3	5.3	107.9	4.5	97.8	3.1	10.1
186	101.8	3.2	98.2	3.7	3.6	101.6	3.7	94.1	2.4	7.5
	Henderson, Kentucky					**Williamstown, Kentucky**				
106	129.8	10.0	109.5	6.7	20.3	115.3	8.0	99.0	4.0	16.3
126	131.0	6.9	114.1	6.5	16.9	118.4	7.4	103.3	5.1	15.1
146	125.5	5.9	112.4	5.0	13.1	116.1	5.6	103.1	4.6	13.0
166	117.6	5.2	107.4	4.1	10.2	110.4	4.5	100.4	3.7	10.0
186	109.0	4.2	100.9	3.2	8.1	103.7	3.5	96.3	2.9	7.4

Table 4. Maximum, minimum, average, and standard deviation of the return due to misting ($/pig/year) by pig placement date for the 22 years of record (1978-1999) for the ten locations in this study.

Pig Placement Date (Julian Day)	Maximum Return $/pig/year	Minimum Return $/pig/year	Average Return $/pig/year	Standard Deviation $/pig/year	Maximum Return $/pig/year	Minimum Return $/pig/year	Average Return $/pig/year	Standard Deviation $/pig/year
	Bardstown, Kentucky				**Lexington, Kentucky**			
106	5.35	1.11	3.07	1.14	7.03	0.74	2.87	1.55
126	6.48	0.60	2.56	1.15	5.24	1.00	2.70	1.03
146	3.76	0.39	2.00	0.80	3.11	0.51	1.87	0.58
166	2.70	0.23	1.24	0.69	2.76	0.15	1.27	0.61
186	2.34	0.02	0.87	0.62	2.14	0.06	0.94	0.50
	Cumberland Gap, Kentucky				**Mayfield, Kentucky**			
106	4.35	0.64	2.05	0.90	7.56	2.49	4.14	1.36
126	2.93	0.81	1.93	0.58	5.36	1.20	3.05	0.94
146	2.64	0.60	1.62	0.52	3.53	0.72	1.90	0.74
166	1.76	0.21	0.99	0.45	2.23	0.19	1.25	0.53
186	1.50	0.0	0.62	0.43	1.80	0.22	0.99	0.48
	Glasgow, Kentucky				**Quicksand, Kentucky**			
106	7.17	1.50	4.16	1.64	3.75	0.19	2.18	1.00
126	5.74	0.96	3.26	1.04	4.40	0.25	1.79	0.88
146	3.93	0.89	2.09	0.93	2.60	0.28	1.46	0.62
166	2.61	0.0	1.39	0.64	2.16	0.23	1.08	0.51
186	1.64	0.0	1.00	0.42	2.14	0.0	0.61	0.55
	Grayson, Kentucky				**Somerset, Kentucky**			
106	3.49	0.34	1.29	0.80	6.40	1.02	2.92	1.07
126	2.98	0.54	1.42	0.73	5.32	1.08	2.65	1.01
146	2.61	0.14	0.81	0.51	4.60	0.78	2.13	0.86
166	2.07	0.0	0.61	0.44	2.53	0.72	1.47	0.48
186	1.24	0.0	0.41	0.35	1.95	0.25	0.89	0.41
	Henderson, Kentucky				**Williamstown, Kentucky**			
106	8.56	1.36	3.87	1.79	5.91	1.71	3.13	1.16
126	5.31	1.18	2.85	1.11	4.06	1.48	2.77	0.74
146	3.37	0.77	1.85	0.83	3.33	0.88	2.07	0.52
166	2.61	0.28	1.34	0.53	2.10	0.72	1.31	0.36
186	1.84	0.0	0.74	0.59	2.32	0.33	0.95	0.44

Figure 2. The simulated yearly net return ($/pig/year) with misting for pigs placed in the growing-finishing facility on July 5 (Julian day 186) and April 16 (Julian day 106) from 1978 through 1999 at the Bardstown, Kentucky, location.



The average yearly return for having a cooling system shown in Table 4 demonstrates that having a misting-cooling facility generally was profitable for most stations in Kentucky and most placement dates and that the average net return due to misting usually decreases as the placement date progresses in time. The largest yearly profits for a cooling system were again found for stations in the western and southern portions of the state (Henderson, Mayfield, and Glasgow), and these returns gradually decreased for the stations in the central and eastern areas. The July 5 (Julian day 186) placement date yielded a minimum yearly return of zero for several stations (Table 4).

Investment Risk Example

One purpose for comparing 22 years of weather data in this analysis is to evaluate various levels of risk that the producer may expect when implementing a misting-cooling system. The swine growth model combined with years of weather and different pig placement dates has determined responses of the animal subjected to many different growing conditions much as would be experienced in a real production situation. If the producer chooses to invest in a cooling system, there is a certain amount of risk in recovering the investment cost over the expected life of the misting system. For example, assume that the investment cost for a misting system is $5.00 per pig space with a seven-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 $1.39 per year if the cost per space is prorated over the seven-year life of the system. Operating costs for the misting system are not considered in this example. As shown by the return due to misting ($/pig/year) in Table 4, a facility with a misting system was generally found on average to be profitable for the 22 years of record. However, Figure 2 demonstrates that the return due to misting can be highly volatile not only by year but also by placement date. It would be beneficial to the producer to have some measure of the risk associated with recovering the initial investment cost.

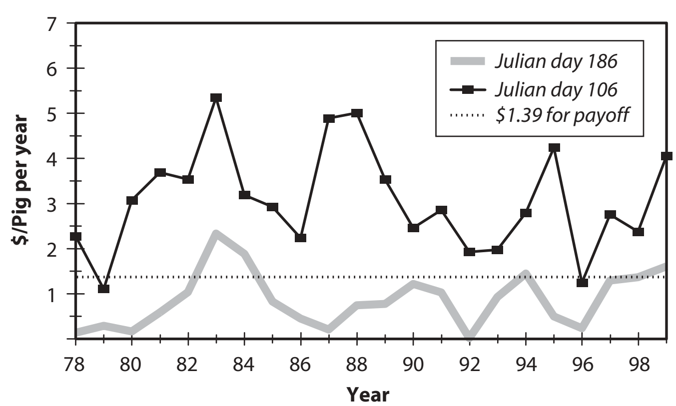
Table 5 presents the probabilities for a net return for cooling the pigs of $1.39 per pig per year required to pay for such a system over its life for each of the ten Kentucky locations by pig placement date. It can be seen from Table 5 that, except for Grayson and Quicksand, the earlier placement dates (Julian days 106, 126, and 146) have a high probability (at least 84%) of achieving the initial investment cost. An 80% probability value would indicate that a facility with misting could be expected to achieve a net return to misting of at least $1.39 in eight out of every ten years. The later placement dates (Julian days 166 and 186) for all stations have a much lower likelihood of achieving the initial investment. Returning to our Bardstown example in Figure 2, Figure 3 illustrates a constant yearly net return to misting of $1.39 per pig per year superimposed on the returns to misting for the April 16 and July 5 placement dates. It can be seen clearly from Figure 3 that for most of the 22-year period of record, the returns due to misting were above the $1.39 threshold value for the earlier date, while few years at the July 5 placement date exceeded this value.

The probabilities (Table 5) indicate the capability of a misting system to recover the initial cost for a given location and date. While misting is still beneficial to the pigs at the later placement dates, it becomes more profitable for the April and May placement dates. When the animals are started in the grow-

Table 5. The probability of a net return (%) due to misting of at least $1.39 per pig per year for the ten locations in this study by pig placement date.

	Pig Placement Date (Julian Date)				
Location	April 16 (106)	May 6 (126)	May 26 (146)	June 15 (166)	July 5 (186)
Bardstown	99.4	97.6	94.5	30.6	4.2
Cumberland Gap	93.9	96.9	84.0	3.6	2.3
Glasgow	99.7	99.8	94.3	50.0	3.2
Grayson	39.6	53.8	1.6	2.4	0.2
Henderson	99.3	99.1	88.8	41.2	17.8
Lexington (Spindletop)	97.1	99.0	95.5	32.3	3.5
Mayfield	99.9	99.7	92.9	27.2	4.5
Quicksand	94.9	84.6	60.4	9.3	0.6
Somerset	99.4	98.9	96.0	65.1	1.2
Williamstown	99.5	99.8	99.1	30.3	2.5

Figure 3. The simulated yearly net return ($/pig/year) with misting for pigs placed in the growing-finishing facility on July 5 (Julian day 186) and April 16 (Julian day 106) from 1978 through 1999 at the Bardstown, Kentucky, location compared to a net return of $1.39 per pig per year necessary for recovery of the system investment.



ing-finishing facility in April and May, they will grow to be larger when the heat is most likely to be at a maximum (June, July, and August), and the pigs will be in greater need of a cooler environment to continue growth and to reduce the effects of heat stress.

Considerations in Use of Results

Based on the data shown in this publication, swine producers should be encouraged to use a misting-cooling system for their growing-finishing facility. In general, these systems will improve the growing pigs' environment, reduce the time to market, and improve profitability. However, these results should be viewed as the "best possible" situation for this type of cooling system, and actual returns may be somewhat lower, depending on individual facility locations and circumstances. This analysis used 22 years of available weather data at each location, and, as other research has shown, longer periods of weather records are desirable. It was also assumed in this analysis that the curtain controller supplies adequate ventilation, which 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 a misting-cooling system 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 relative humidity. The solar heat load on the facility was not considered in this analysis, and periodically this may be significant enough to lower the expected temperature reductions that misting-cooling normally achieves. For facilities using flush systems, the inside relative humidity will be higher, which could reduce the potential temperature decrease accomplished by the misting system.

References

Bridges, T.C., L.W. Turner, T.S. Stahly, J.L. Usry, and O.J. Lower. 1992a. Modeling the physiological growth of swine. Part 1: Model logic and growth concepts. Transactions of the American Society of Agricultural Engineers (ASAE) 35(3):1019-1028.

Bridges, T.C., L.W. Turner, J.L. Usry, and J.A. Nienaber. 1992b. Modeling the physiological growth of swine. Part 2: Validation of model logic and growth concepts. Transactions of the ASAE 35(3):1029-1033.

Bridges, T.C., R.S. Gates, J.L. Usry, and L.W. Turner. 1992c. Stochastic assessment of evaporating misting for growing-finishing swine in Kentucky. Applied Engineering in Agriculture 8(5):685-693.

Bridges, T.C., L.W. Turner, and R.S. Gates. 1998. Economic evaluation of misting-cooling systems for growing-finishing swine through modeling. Applied Engineering in Agriculture 14(4):425-430.

Bridges, T.C., L.W. Turner, R.S. Gates, and D.G. Overhults. 2000. Swine performance enhancement with cooling as influenced by summer growth period and weather. Proceedings of the First International Conference on Swine Housing, Des Moines, Iowa, October 9-11, 2000.

Gates, R.S., and M.B. Timmons. 1988. Method to assess economic risk applied to environmental control options for animal housing. Transactions of the ASAE 31(1):197-201.

Turner, Larry, Thomas C. Bridges, Richard Coffey, Richard S. Gates, Gary Parker, Tami Brown-Brandl, and Doug Overhults. 1998. Comparison of observed and simulated growing-finishing swine performance under summer conditions. Applied Engineering in Agriculture 14(4):419-423.

Usry, J.L., L.W. Turner, T.C. Bridges, and J.A. Nienaber. 1992. Modeling the physiological growth of swine. Part 3: Heat production and interaction with environment. Transactions of the ASAE 35(3):1035-1042.

Issued 12-2003