Final Report to the Minnesota Pork Board
Funded by the Pork Checkoff
September 30, 2011
Amended 10/18/11

Reducing Energy Consumption in Swine Nurseries with Reduced Nocturnal Temperature

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Abstract

Swine nursery facilities in four states were used to evaluate the utility of reducing room temperature at night with the hope of reducing fossil fuel consumption without compromising pig growth performance. Four stations (University of Minnesota, University of Missouri, The Ohio State University, South Dakota State University) completed at least two replicate trials of this experiment during winter and early spring. Each trial lasted 28 to 42 days. One of two temperature treatments was imposed in two identical nursery rooms at each station. In the control rooms (CON; n = 9), temperature controllers were set at 86 °F for the first week and reduced by 3.5 °F per week throughout the remainder of the trial. Day- and night-time temperature settings were the same in CON rooms. In the Reduced Nocturnal Temperature rooms (RNT; n = 10), temperature controllers were at 86 °F for the first four days after arrival of pigs. Beginning on day 5, daytime temperatures were set to equal the CON room but ventilation controllers were set to reduce nighttime temperature by 15 °F from 1900 to 0700 hours. Daytime temperature in the RNT room was also reduced 3.5 °F per week during the remainder of the study. Each room was independently monitored for consumption of heating fuel (propane or natural gas) and electricity. Rooms were assigned randomly to experimental treatments and pigs were assigned randomly to rooms. Weight gain and feed consumption of pigs were recorded on a room basis as was use of fossil fuels. The statistical model for analysis of data included fixed effects of temperature treatment, station, and their interaction and random effects of replicate. Neither final pig weight (48.0 vs 47.4 lb), average daily pig weight gain (0.99 vs. 0.98 lb), average daily feed intake of pigs (1.35 vs. 1.33 lb) nor efficiency of gain (0.75 vs. 0.75) were different for pigs housed in CON or RNT rooms, respectively. Likewise, pig mortality (1.5% vs. 1.2%) was not different for pigs in CON and RNT rooms, respectively. We observed a consistent reduction in use of heating fuel and electricity in RNT rooms for all four stations. Consumption of heating fuel (7,061 vs 10,019 Btu/pig-day) and electricity (0.021 vs 0.026 KWH/pig-day) were significantly lower in the RNT rooms compared with CON rooms. On average, we documented a 29% reduction in heating fuel use and a 19% reduction in electrical

use. These energy savings are valued at $1.71 (propane cost = $1.60/gallon) and $0.02 (electricity cost = $0.10/ KWH) per pig leaving the nursery. It appears that a RNT regimen is effective in reducing energy costs in the nursery without compromising pig growth performance or health.

Introduction

The recent high costs for fossil fuels have caught the attention of American agriculture and pork producers are no exception. Pork producers feel the effects of these high fuel costs imbedded in the prices they pay for feed grains, supplies, livestock transport, professional services, and other inputs. Their most direct reminder of high fossil fuel prices comes when they pay the bill for heating their production facilities. In most instances, pork producers have no direct control of these costs with the exception of the fossil fuel used to heat their barns. According to Minnesota Farm Business Management (2007) records, pork producers spent $1.72 per head in heating and utility costs for each pig raised from weaning to 58 pounds and another $1.33 per head to carry that pig to market weight in 2007. Producers have direct control of how they heat their barns and can resolve to reduce consumption of fossil fuels. By reducing consumption of fossil fuels, pork producers can reduce costs and decrease emissions of greenhouse gases making their production system more environmentally friendly.

In the 1980's and early 1990's, researchers at the University of Nebraska studied the effects of Reduced Nocturnal Temperature (RNT) on pig performance and fossil fuel consumption in swine nurseries. In their initial studies (Brumm et al. 1985), room temperature in the control room was set at 86 °F the first week after weaning and decreased by 3.6 °F per week for four weeks. In the RNT room, temperature was maintained at the same level as the control rooms during the day but reduced 9 °F from 1900 to 0700 h for three nights then reduced by 18 °F for four nights in the first week. In the remaining four weeks, night time temperatures were reduced by 18 °F in the RNT room. They reported improved daily weight gain due to increased feed intake for pigs housed in the RNT room. However, there was a higher mortality rate in the RNT rooms especially when pigs experienced a health challenge (scouring). In subsequent studies, these researchers delayed implementing the RNT regimen until one week after pigs arrived in the nursery. The control room was started at 86 °F and reduced 3.6 °F per week. The RNT rooms followed the same daytime temperature pattern as the control room but temperature was reduced 11 °F from 1900 to 0700 hours each night. Pig performance was unaffected by the RNT regimen while there was a significant savings in propane and electricity (Brumm and Shelton, 1988; Brumm and Shelton, 1991). Other studies from this group evaluated an 18 °F temperature reduction at night and found that pig performance was not affected by RNT but morbidity and mortality increased (Brumm and Shelton, 1991). It appears that nursery pigs can handle an 11 °F nighttime drop in temperature but health challenges become more prevalent if nighttime temperatures drop 18 °F. These results are not surprising when one considers that nursery pigs prefer cooler nighttime temperatures when offered a choice (Bench and Gonyou, 2007).

Recently, our research group has begun to re-evaluate the RNT management practices with modern genetics and production facilities. In the 15 to 25 years since the Nebraska group first studied RNT, many aspects of pork production have changed. Most importantly, the modern swine industry produces a very different pig than was common in the 1980's. Current genetics are leaner and faster growing than the genetics used by the Nebraska group. This genetic change has influenced energetics of the pig. Harmon et al. (1997) demonstrated that newer genetic lines display increased heat production. In a review of the literature on metabolic heat production, Brown-Brandl (2004) concluded that fasting heat production increased 18.1% from 1984 to 2002 (approximately 1% per year) as a result of increased lean tissue accretion rates. This fact alone could influence the pig's response to RNT regimens. There have also been important changes in building design, environmental controllers, flooring materials, health status of pigs, nutrition programs, and biosecurity practices. All of these changes could conceivably alter the pig's response to RNT regimens. Our initial study (Thaler et al., 2008) evaluated an 11 °F reduction in room temperature from 1900 to 0700 hours beginning one week after pig placement in the nursery. Across the four universities (Univ. of Minnesota, South Dakota State Univ., Univ. of Nebraska and Univ. of Missouri) that participated, we found no difference in pig performance and important reductions in fossil fuel use. We observed numerical reductions in heating fuel and electrical use that totaled 17% and 11%, respectively. These results made us wonder if a more aggressive RNT regimen in the nursery could result in larger reductions in consumption of fossil fuels.

Objectives

Objective 1: To determine the effects of a reduced nocturnal temperature regimen on consumption of fossil fuels under modern production conditions

Objective 2: Document effects on performance and health of modern pigs subjected to a RNT regimen

Procedures

This study was conducted as a collaborative effort among researchers at the University of Minnesota, University of Missouri, The Ohio State University, and South Dakota State University. Each participating station completed at least two replicate trials. Each trial lasted 28 to 42 days depending on the pig production flow at the research location for each station.

One of two temperature treatments were imposed randomly on two identical nursery rooms at each participating station. Temperature treatments were Control (CON) and Reduced Nocturnal Temperature (RNT). In the CON rooms, temperature controllers were set at 86 °F for the first week and reduced by 3.5 °F per week throughout the remainder of the trial. Day- and night-time temperature settings were the same in CON rooms. In the RNT rooms, temperature controllers were at 86 °F for the first four days after arrival of pigs. Beginning on day 5, daytime temperatures were set to equal the CON room but ventilation controllers were set to reduce nighttime temperature by 15 °F from 1900 to 0700 hours. Daytime temperature in the RNT room was also reduced 3.5 °F per week during the remainder of the study. Each room was independently equipped with an electric meter (except Ohio) to record electrical use in the room. Operation time for lights and supplemental heat lamps were kept constant between CON and RNT rooms. Weekly consumption of heating fuel (propane or natural gas) was either recorded directly for each room or calculated from the measured operation time of furnaces in each room.

One gallon of propane was assumed to contain 91,547 Btu's and one cubic foot of natural gas was assumed to contain 1,000 Btu's for calculation of heating fuel use. Room temperatures were recorded at pig level in two or three locations in each room throughout the experiment using automated data recording devices (Hobo recorders). Temperatures were recorded every 5 minutes throughout the experiment. Recorded temperatures were averaged across each recorder at each time and one average temperature for the daytime (0700 to 1900 hours) and nighttime (1900 to 0700 hours) were used in data analysis.

Pigs were assigned randomly to experimental rooms and temperature treatments in the first replicate were assigned randomly to rooms. Room temperature treatments were switched between rooms for the second trial at each location. Within rooms, pigs were assigned randomly to pens based on the normal operating procedures of the unit. At each station, total number and weight of pigs entering and leaving each room were recorded. In addition, total consumption of feed by pigs in each room was recorded. At the University of Missouri and South Dakota State University, individual pig weight was recorded on all pigs at entry to the nursery room and weekly throughout the experiment. Similarly, feed disappearance on a pen basis was recorded weekly. At the University of Minnesota, pig weight and feed disappearance on a pen basis were recorded on a random subsample of pigs (15 pens of 9 pigs/pen in each room) initially and weekly throughout the experiment. Pig weights but not feed intake were recorded on a pen basis weekly throughout the experiment at the Ohio station. Number of pigs that died, pigs that received individual treatments for ill health, and total number of days pigs received individual health treatments were recorded for each room. Pigs were fed nutritionally adequate diets as per normal operating procedures at the research site. Pigs had ad libitum access to feed and water throughout the experiment.

Statistical analysis of data was accomplished using the PROC MIXED procedure of SAS with repeated measures where appropriate. The initial statistical model included the fixed effects of temperature treatments (CON or RNT), station, and their interaction. When the interaction was not significant, it was removed from the statistical model for the final analysis. Replicate nested within station was included in all statistical models as a random effect. Room served as the experimental unit in the statistical analysis. Separation of means was accomplished using the PDIFF option of SAS with the Tukey adjustment for multiple comparisons. Level of statistical significance was set at $P < 0.05$ with $P < 0.10$ indicating a significant trend.

Results and Discussion

Ten replications of this experiment were conducted beginning in December, 2009 and continuing through March, 2011 at the four participating stations (Table 1). The research in Ohio was conducted at a commercial nursery with limited capabilities to weigh individual pigs. In South Dakota and Missouri, the experiment was conducted at smaller research facilities so the size of pig groups was smaller which allowed more intensive measurement of pig performance. In Minnesota, a near-commercial sized nursery was used but a sub-sample of pigs was selected for weekly monitoring of pig performance. The Minnesota station contributed two additional replicates of data because a computer error prevented retrieval of heating fuel use in the first two replicates resulting in pig performance data from four replicates and heating fuel use from two replicates. All experiments were conducted during the winter and early spring to optimize the chances of achieving the desired differences in nighttime room temperatures. The Minnesota station also recorded pig behavior for 24 hours on days 3 and 17 after implementation of reduced nighttime temperatures in each replicate using video-recording cameras. Videotaping of pig behavior was not part of the original scope of work for this project but will be reported in a later publication.

There were no significant temperature treatment by station interactions for overall growth performance. Lack of significant interactions between temperature treatments and station suggest that the effects of RNT are consistent across the four stations that contributed data to this study. There were no significant effects of station on any of the overall growth performance traits. Neither initial and final pig weight, average daily weight gain, average daily feed intake nor gain efficiency were influenced by the RNT treatment (Table 2). Pig performance over the entire trial was not statistically different between pigs housed in the CON rooms compared to those housed in RNT rooms. This lack of difference between CON and RNT rooms for pig performance was consistent throughout the experiment. No temperature treatment effects or treatment by time interactions were observed for body weight of pigs (Figure 1), average daily gain (Figure 2), average daily feed intake (Figure 3) or efficiency of gain (Figure 4). Absence of a treatment by time interaction suggests that pigs adapted to the reduced nocturnal temperature very quickly because they did not exhibit reduced performance in the first week of cooler nights. Average room temperature during the day (0700 to 1900 hours) was significantly cooler in the RNT room when compared with the CON rooms (Table 2). This is likely due to the time necessary to warm the RNT rooms back up to the same temperature as the CON rooms each morning beginning at 0700 hours. As designed, the RNT rooms were significantly cooler during the nighttime hours (1900 to 0700 hours). However, we were not able to achieve the desired 15 °F depression in nighttime temperature for the RNT rooms. At three stations, the controller was set to a new lower room temperature at night and the room was allowed to cool down to the new target temperature. At the site in South Dakota, the controller reduced the target temperature for the heater in RNT rooms and increased ventilation rate to cool the room down to the new target over a period of 2 hours.

The inability to achieve the desired temperature depression most likely was due to increased heat generation of the pigs as they grew larger. According to Harmon et al. (1997), sensible heat production increases from about 60 Btu/hour for pigs weighing 15 lb to 137 Btu/hour for pigs weighing 25 lb. The research of Brown-Brandl et al. (2004) suggests sensible heat production increases further to 217 Btu/hour as pigs reach a body weight of 50 lb. These estimates could be reasonably increased 10% to account for genetic improvements in pig growth rate and leanness over the last 10 years since Harmon and Brown-Brandl conducted their work. This indicates that sensible heat production increases from about 65 Btu/hour when pigs weigh 15 lb to 240 Btu/hour when pigs weigh 50 lb. This nearly four-fold increase in heat production by pigs as they grew surely contributed to heat supply for the room and likely explains why we could not achieve a 15 °F spread in nighttime room temperatures between CON and RNT. In Minnesota, after about 14 days on the RNT regimen, heaters in the RNT rooms did not run at all from 1900 to 0700 hours suggesting that no supplemental heat was necessary to maintain target room temperatures. With no heater running, the only source of heat could be the pigs themselves. This observation is supported by the average weekly daytime and nighttime temperatures recorded in the CON and RNT rooms (Figure 5). Temperatures in RNT rooms at night dropped precipitously during the first 5 to 14 days of the RNT regimen compared to CON rooms but only continued to decline very gradually in the later periods of the experiment. These patterns of change in nighttime temperatures mirrored the changes reported by Brumm and Shelton (1988, 1991, 1995). Obviously, the ability to achieve this temperature depression is a function of building design, wall and ceiling insulation, ventilation rates, and pig size and will vary tremendously among nursery barns. The lack of differences in pig performance observed between RNT and CON rooms was observed at every participating station (Table 3). Mortality and morbidity of pigs in CON and RNT rooms were not different (Table 4) indicating that pig health was not adversely affected by reducing temperature in rooms at night.

Even with small differences in room temperature at night, we observed significant reductions in Btu's per pig-day in the RNT rooms compared with CON rooms (Table 2). Heating fuel used in each room expressed as Btu's per pig leaving the nursery was not significantly different between RNT and CON rooms. This lack of statistically significant differences is likely due to the extreme variation in this measurement indicated by the very large standard error and the varying length of the trials at the different stations. Heating fuel use in RNT rooms was 29% lower than in CON rooms. At every station, heating fuel use was numerically lower in RNT rooms compared to CON rooms (Table 3) and the magnitude of these differences ranged from a 49% reduction (MN) to a 15% reduction (MO). The consistent direction of response at each station provides some confidence that producers will be able to consistently reduce heating fuel consumption with RNT regimens in nursery barns. The actual quantity of heating fuel used at each station varied tremendously. In some cases such as Ohio and Missouri, the quantity of heating fuel consumed per pig leaving the nursery may be greater than typical usage rates on many commercial farms. Differences in fuel usage across stations were expected because of differences in geographical location and management of the facility. The important observation with regard to fuel savings is that every station recorded less heating fuel consumption in the RNT rooms regardless of whether the station had the highest (OH and MO) or lowest (MN) fuel use per pig produced. In this experiment, the relative differences between CON and RNT rooms are more informative than the absolute quantity of heating fuel consumed in each room.

Similar to heating fuel, use of electricity expressed as KWH per pig-day was lower ($P < 0.05$) in RNT rooms compared to CON rooms. While not measured directly, we assume most of the savings in electricity use resulted from decreased operation time for heaters during the nighttime hours in RNT rooms compared to CON rooms.

The savings of heating fuel are greater than in our previous study. Thaler et al. (2008) reported a numerical reduction in heating fuel of 17% when the RNT regimen was implemented one week after pigs arrived in the nursery and targeted a 10 °F nighttime temperature reduction. Similar to the current study, this savings in heating fuel was not statistically significant due to the high variation in the response but each participating station measured a reduction in heating fuel consumption. In the current study, implementing the RNT regimen on the fourth day after pigs arrived and increasing the targeted nighttime temperature reduction to 15 °F increased the savings in heating fuel to about 32% over the entirety of the experiment. This fuel savings was realized without a reduction in pig performance or health. In the original RNT trials of Brumm and Shelton (1985), propane use was reduced by 31.8% and electricity use by 19.0% (Shelton and Brumm, 1986).

The consistent pattern of reductions in the fossil fuel use among all four participating stations provides some measure of confidence that an RNT regimen will save fuel on commercial farms. Using data in Table 2, the RNT regimen saved 98,094 Btu of heating fuel (1.07 gallons propane) and 0.16 KWH of electricity for every pig leaving the nursery. Assuming the cost of propane is $1.60/gallon and electricity is $0.10/KWH, the RNT regimen saved $1.71/pig in heating fuel and $0.02/pig in electricity for a total savings of $1.73/pig leaving the nursery. Across stations, these savings ranged from $3.28/pig in Ohio which reported one of the highest uses of heating fuel to $0.51/pig in Minnesota which had the lowest fuel consumption. In our previous study using a higher price for propane ($2.00/gallon) and a lower price for electricity ($0.08/KWH; Thaler et al., 2008), we found savings of $1.60/pig ($1.55 for heating fuel and $0.05 for electricity). Savings would climb to $2.11/pig ($2.10 for heating fuel and $0.01 for electricity) if we used prices reported by Thaler et al. (2008) to calculate the value of fuel savings in the current study.

Summary

Ventilation controllers in RNT rooms were set to a target nighttime temperature (1900 h to 0700 h) 15 °F below that of CON rooms beginning on day 5 after pigs arrived in the nursery. We were not able to maintain this temperature difference throughout the experiment probably due to the increasing heat production of pigs as they grew larger. However, RNT rooms were 4.5 °F cooler at night throughout the experiment which resulted in a 29% reduction in heating fuel consumption for RNT rooms. Reducing the nighttime temperature elicited no differences in growth performance of pigs, pig mortality or incidence of ill-health in pigs. Implementation of the RNT regimen in this study resulted in a savings or $1.73/pig leaving the nursery.

Acknowledgements

The authors express appreciation to Ms. Adrienne Hilbrands, University of Minnesota, for data manipulations and statistical analysis of data and the Minnesota Pork Board for financial support of this study.

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Table 1. Participating stations, time periods for each replicate, and size of each replicate

Station	Dates	# of Pigs	# of Pigs/Room[1]	
			CON	RNT
OH	1/12/10 – 2/23/10	700	350	350
	3/24/10 – 5/5/10	720	360	360
SD	1/3/10 – 2/7/10	50	0	50
	2/14/11 – 3/21/11	100	50	50
MO	3/3/10 – 4/7/10	180	90	90
	12/2/10 – 1/7/11	180	90	90
MN	12/22/09 – 1/27/10	536 (270)[2]	268 (135)	268 (135)
	2/2/10 – 3/9/10	595 (270)	297 (135)	298 (135)
	11/23/10 – 12/21/10	607 (270)	303 (135)	304 (135)
	1/4/11 – 2/1/11	630 (286)	314 (143)	316 (143)

[1]CON = Control treatment; RNT = Reduced nocturnal temperature treatment.
[2]Number in parenthesis indicates number of pigs included in weekly performance measures.

Table 2. Effect of reduced nocturnal temperature on nursery pig performance and energy use

Trait	CON	RNT	PSE[1]
No. of observations	9	10	--
Initial pig wt., lb	13.8	13.7	0.36
Final pig wt., lb	48.0	47.4	1.41
Avg. daily gain, lb	0.99	0.98	0.036
Avg. daily feed intake, lb	1.35	1.33	0.042
Gain/feed	0.75	0.75	0.012
Avg. daytime room temp., °F	77.4[a]	76.1[b]	0.95
Avg. nighttime room temp., °F	76.9[a]	72.4[b]	0.66
Heating fuel used:[2]			
Btu/pig-day	10,019[a]	7,061[b]	1,467
Btu/pig[3]	343,942	245,848	1.08×10^5
Electricity used:[4]			
KWH/pig-day	0.026[a]	0.021[b]	0.0036
KWH/pig	0.86[a]	0.70[b]	0.116

[1]Pooled Standard Error.
[2]No. of observations were 7 and 8 for CON and RNT, respectively.
[3]Total Btu's consumed for heating over entire study period divided by number of pigs leaving the room.
[4]No. of observations were 5 and 6 for CON and RNT, respectively.
[ab]Within a row, means with a different superscript differ ($P < 0.05$).

Table 3. Effect of reduced nocturnal temperature on pig performance and energy use by participating station[1,2]

	Ohio		Missouri		South Dakota		Minnesota		
Trait	CON	RNT	CON	RNT	CON	RNT	CON	RNT	PSE[3]
No. of observations	2	2	2	2	1	2	4	4	--
Initial wt., lb	14.7	14.0	14.9	15.1	12.4	12.0	13.4	13.5	0.18
Final pig wt., lb	43.1	40.2	52.7	53.3	38.3	44.4	44.4	43.6	10.52
Avg. daily gain, lb	0.88	0.81	1.13	1.15	0.82	0.99	0.95	0.93	0.008
Avg. daily feed intake, lb	1.42	1.22	1.55	1.55	1.45	1.55	1.58	1.56	0.004
Gain/feed	0.67	0.68	0.79	0.81	0.61	0.68	0.62	0.61	0.007
Avg. daytime room temp., °F[a]	76.1	75.8	80.8	80.7	79.1	75.2	73.7	73.0	0.95
Avg. nighttime room temp., °F[b]	75.3	72.1	80.1	73.0	78.5	72.9	73.7	71.8	0.66
Heating fuel used:									
Btu/pig-day	14,307	8,943	14,104	12,030	7,935	5,714	3,009	1,557	6.68×10^6
Btu/pig[4]	500,754	313,064	501,814	423,626	277,731	200,944	88,367	45,758	7.98×10^9
Electricity used:									
KWH/pig-day	ND[5]	ND	0.020	0.019	0.043	0.036	0.032	0.026	0.00001
KWH/pig	ND	ND	0.57	0.55	1.39	1.13	1.00	0.83	0.011

[1]Station effects were significant ($P < 0.05$) for all variables.
[2]Trial duration: MN (replicates 3 & 4) = 28 days; MN (replicates 1 & 2), MO, SD = 35 days; OH = 42 days.
[3]Pooled standard error.
[4]Total Btu's consumed for heating over entire study period divided by number of pigs leaving the room.
[5]Not Determined.
[a]Room temperature treatment ($P < 0.06$) and treatment x station ($P < 0.05$) effects.
[b]Room temperature treatment ($P < 0.01$) and treatment x station ($P < 0.01$) effects.

Table 4. Effect of reduced nocturnal temperature on pig mortality and morbidity

Trait	CON	RNT	P value[1]
No. dead pigs	32	26	0.84
No. sick pigs	41	49	0.59
No. pig treatment days	98	97	0.45

[1]P value from Chi-square analysis.

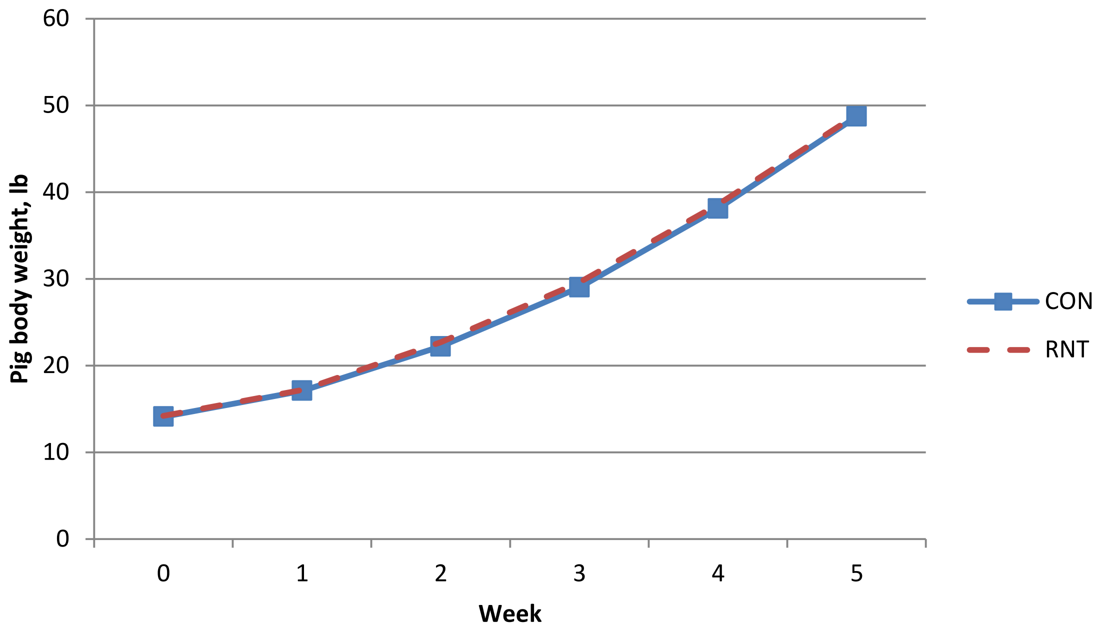

Figure 1. Effect of CON and RNT regimens on changes in pig body weight throughout the experiment

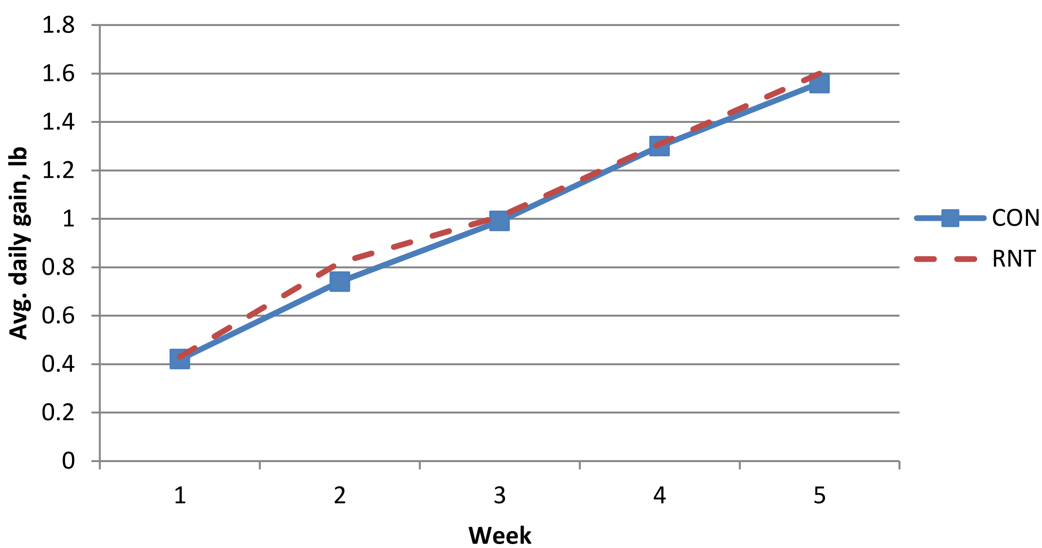

Figure 2. Effect of CON and RNT regimens on average daily weight gain of pigs throughout the experiment

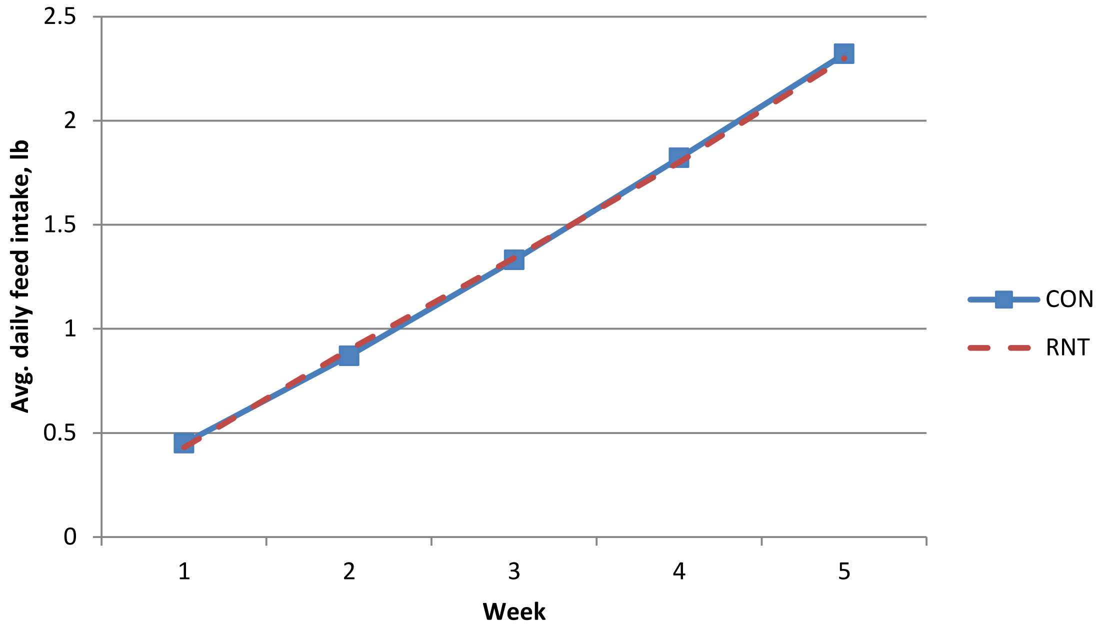

Figure 3. Effect of CON and RNT regimens on average daily feed intake of pigs throughout the experiment

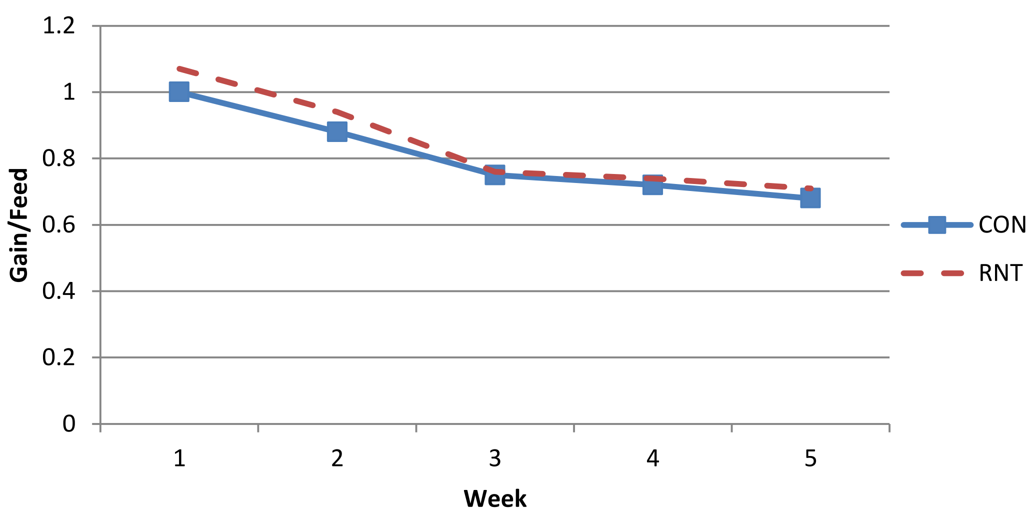

Figure 4. Effect of CON and RNT regimens on efficiency of gain for pigs throughout the experiment

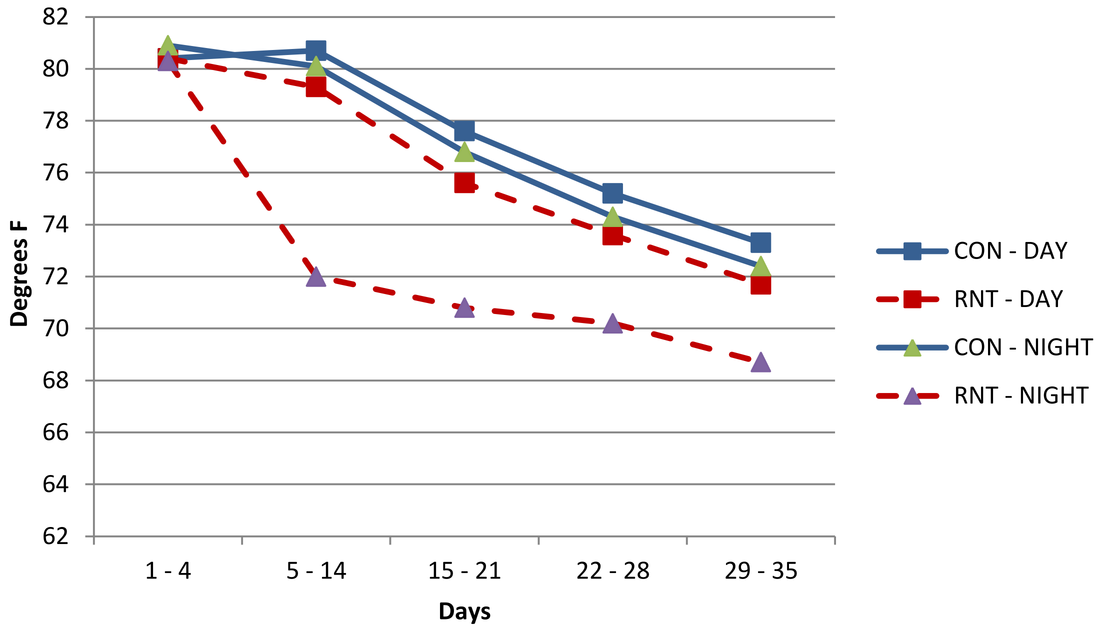

Figure 5. Average day- and night-time temperatures in CON and RNT rooms over the course of the experiment.