RESEARCH REPORT
ANIMAL SCIENCE

Title: The effects of increasing niacin supplementation on growth performance, and pork quality of finishing pigs raised in seasonal heat stress. **NPB # 13-093**

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Date Submitted: July 1, 2014

Industry Summary:

The overall hypothesis was that increasing the supplementation of niacin to finishing pigs during periods of heat stress can increase skin vasodilation which will improve heat abatement and result in a pig that exhibits fewer signs of heat stress. The overall goal of this research was to find a dietary means to help mitigate the negative effects associated with seasonal heat stress on pig performance and potentially improve pork quality.

The current study suggests that additional supplementation of niacin above the animal's requirement (14 mg/lb) does not influence ADG or F/G. It should be noted that the main objective of this experiment was not to evaluate the finishing pig's niacin requirement, as the increasing levels tested were 12 to 33 times requirement (172, 331, 490 mg/lb) which were selected for heat stress abatement potential and based off of research conducted in other species.

For pork quality, the current study suggests that supplementation of niacin at levels 12 to 330 times above the pig's niacin requirement does not drastically impact pork quality. This contrasts with previous meat quality research which observed improved color and pH with increasing niacin supplementation up to 249 mg/lb. The reasons for the different findings are currently unknown.

As a primary objective, the study was designed to evaluate the influence of increasing dietary niacin in a heat stressed environment. This experiment was conducted in a commercial research-finishing barn in southwestern Minnesota and started June 13th and ended September 18th, 2013. The barn was naturally ventilated and double-curtain sided with completely slatted flooring and a deep pit for manure storage. The daily average temperature ranged from 63.8 to 85.5 °F and daily average humidity ranged from 44.9 to 85.5%. Unfortunately the barn environmental conditions did not achieve both the expected average and high temperatures and humidity as documented in previous year's summer months. As a result, the degree of seasonal heat stress

observed during this study was less than anticipated which may have influenced the lack of response to increasing dietary niacin. This may also explain why we did not observe consistent treatment differences in pig rectal temperatures as well as shoulder and rump skin temperatures. Within the environmental conditions present at the time this study was conducted, increasing niacin was not effective in mitigating any heat stress that might have been present.

Producer bottom line:

1) Additional niacin above the pig's requirement does not influence growth, carcass or meat quality.
2) Increasing niacin did not influence pig rectal temperatures or shoulder and rump surface temperatures nor did it ameliorate any other indication of heat stress; however, the amount of heat and humidity present at the time this study was conducted was less than anticipated.
3) Due to the success of niacin to reduce heat stress in other species, specifically dairy cattle, more research is needed in a more adverse heat and humidity environment to fully determine if increasing dietary niacin will impact heat stress of pigs.

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Keywords:

Heat stress, niacin, nicotinic acid, finishing pigs, meat quality, finishing pig, growth

Scientific Abstract:

A total of 1,232 pigs (PIC 337 × 1050; initially 59.4 lb) were used in a 98-d study to evaluate the influence of increasing dietary niacin supplementation on growth, body temperatures, and meat quality of pigs raised in a commercial facility during the summer. There were 28 pigs per pen and 11 pens per treatment. Basal diets contained corn, soybean meal, and dried distillers grains with solubles (DDGS). The four dietary treatments were formed by adding increasing levels of nicotinic acid as the source of niacin (Lonza, Allendale, NJ) at 14, 172, 331, and 490 mg/lb of complete feed. Temperature loggers were placed in the barn to determine daily relative humidity and temperatures. On d 57, 58, and 59, rectal temperatures and skin temperatures on the top of the shoulder and rump were collected from 2 pigs per pen (1 barrow and 1gilt). Temperatures were collected on the same pigs within the pen at 6:00, 9:00, 12:00, 15:00, and 18:00 of each collection day. On d 98, 2 pigs per pen (1 barrow and 1gilt) were visually selected as the heaviest pigs in the pen and were harvested for carcass and meat quality data. Pigs were harvested at a commercial abattoir where carcass traits, pH decline, and subjective loin color and marbling scores were collected. Afterwards, a 15.7 in. segment of the loin (posterior end) was used for meat quality analysis including measurements of ultimate pH, and purge loss. Then 1 in. boneless chops were cut from the loin segment and were used to determine 24 h drip loss, subjective color and marbling, objective lean color values (L*, a*, b*), and muscle niacin concentrations.

Temperature loggers reported average daily temperatures within the barn ranged from 63.8 to 85.5° F throughout the length of the study, with daily low temperatures ranging from 59.9 to 81.0° F and daily high temperatures ranging from 66.1 to 93.3° F. Overall, temperature was cooler than expected for the facility compared to normal seasonal increases associated with the summer months. Humidity was variable throughout the length of the study but was within expected ranges with the average humidity ranging from 44.9 to 85.5%.

Time × day interactions ($P < 0.01$) were observed for rectal, shoulder, and rump temperatures. Increasing dietary niacin increased rectal temperature (linear; $P = 0.02$) at 6:00 on d 57, but at 12:00 on d 57 increasing niacin decreased rectal temperature (quadratic; $P = 0.03$). Shoulder temperatures were increased (linear; $P = 0.04$) with increasing dietary niacin on d 57 at 6:00; however, temperatures were decreased with increasing niacin at 9:00 and 12:00 (quadratic; $P < 0.05$) on d 57, and at 6:00 (quadratic; $P = 0.04$) and 9:00 (linear; $P = 0.05$) on d 58. Rump temperatures were decreased at 9:00 (quadratic; $P = 0.04$) on d 57 and at 9:00 (linear, $P = 0.05$) on d 58 as niacin increased in the diet.

Overall (d 0 to 98), increasing dietary niacin did not influence ADG, or F/G but it tended (linear; $P = 0.07$) to increase ADFI. Increasing niacin supplementation did not influence carcass traits; however, for meat quality, it did increase (linear; $P < 0.01$) pH decline at 45 min and 21 h postmortem. Increases (linear; $P < 0.05$) in a* and b* were observed for chops from pigs fed increasing niacin, but subjective chop color scores were not affected by increasing niacin supplementation.

Introduction:

Niacin is a component of the coenzymes nicotinamide-adenine dinucleotide (NAD) and nicotinamide-adenine dinucleotide phosphate (NADP). These coenzymes are required for the normal metabolism of carbohydrates, proteins, and fats due to their reducing and oxidizing abilities. There are two main forms of niacin available for use as supplements in swine diets; these are nicotinamide and nicotinic acid. Both forms act as exogenous

precursors for the metabolically active forms of the vitamin (NAD and NADP); however, nicotinic acid is also known for other functions in the body. In human medicine, pharmacological doses of nicotinic acid are commonly used to help reduce circulating lipid concentrations by reducing LDL and vLDL cholesterol and increasing HDL cholesterol. One of the largest side effects associated with pharmacological dosing of nicotinic acid is an increase in skin vasodilation known as "flushing". Although it is seen as a negative side effect in humans, this increase in vasodilation could potentially act as a mediator of seasonal heat stress in swine by increasing blood circulation to the periphery of the body allowing for increased heat abatement by the animal.

Heat stress is a major contributor to seasonal losses experienced in pig production. Economic losses were estimated to total approximately $200 million dollars (St-Pierre et al., 2003[1]) in the grower and finishing pig sector in the form of decreased performance, lowered market weights, increased days on feed, and mortality of finishing pigs. Previous research by Zimbelman et al. [2] (2010) in dairy cows concluded that niacin was successful at reducing heat stress in milking cows during periods of high temperatures in the form of reduced rectal and vaginal temperatures and increased evaporative heat loss. No research has examined the influence of pharmacological doses of nicotinic acid on growing and finishing pig performance during seasonal heat stress.

Other interests associated with niacin supplementation in finishing pigs are potential influences on carcass meat quality. Real et al. (2002[3]) examined the influence of nicotinic acid supplementation on meat quality of commercially reared pigs and concluded that increasing nicotinic acid supplementation from 0 to 227 mg/lb of complete feed increased 24 h pH and improved meat color.

Objectives:

The specific objectives were:

1) To evaluate growth performance, and body temperatures of finishing pigs supplemented fed diets supplemented with varying levels of niacin when pigs are raised in seasonal heat stress (summer).

2) To determine if increased niacin supplementation improves pork quality.

Materials & Methods:

Experimental procedures and animal care were approved by the K-State Institutional Animal Care and Use Committee. This experiment was conducted in a commercial research-finishing barn in southwestern Minnesota. The barn was naturally ventilated and double-curtain sided with completely slatted flooring and a deep pit for manure storage. Pens were equipped with a cup waterer and 4-hole stainless steel dry feeder (56 in. wide) manufactured by Thorp Equipment, Inc. (Thorp, WI) to provide ad libitum access to feed and water. Daily feed additions to each pen were accomplished through a robotic feeding system (FeedPro; Feedlogic Corp., Willmar, MN) capable of providing and measuring feed deliveries on an individual pen basis.

[1]St. Pierre, N. R., B. Cobanov, and G. Schnitkey. 2003. Economic losses from heat stress by US livestock industries. J. Dairy Sci. 86(E-suppl.):E52-E77.

[2] Zimbelman, R. B., L. H. Baumgard, and R. J. Collier. 2010. Effects of encapsulated niacin on evaporative heat loss and body temperature in moderately heat-stressed lactating Holstein cows. J. Dairy Sci. 93:2387-2394.

[3] Real, D. E., J. L. Nelssen, J.A. Unruh, M. D. Tokach, R. D. Goodband, S. S. Dritz, J. M. DeRouchey, and E. Alonso. 2002. Effects of increasing dietary niacin on growth performance and meat quality in finishing pigs reared in two different environments. J Anim. Sci. 80:3203-3210.

Due to an electrical malfunction in the barn, only data through d 98 was able to be utilized for the study. Thus growth, barn environmental conditions, pig thermal conditions, and carcass characteristics and meat quality of pigs markets on d 98 are included.

Pigs and Dietary Treatments

A total of 1,232 pigs (PIC 337 × 1050; initially 59.4 lb) were used in a 98 d study. At initiation of the study, pens were allotted to treatments in a randomized complete block design with location within barn as the blocking factor. There were 4 dietary treatments with 11 pens per treatment.

The 4 dietary treatments were increasing levels of nicotinic acid (Lonza, Allendale, NJ) at 14, 172, 331 and 490 mg/lb (Table 1). Diets were formulated such that the first diet met the pig's estimated requirement (14 mg/lb) for niacin with further additions exceeding the niacin requirement. The basal diet was corn-soybean meal-based and contained 10% dried distillers grains with solubles. Diets were formulated to meet or exceed the nutrient requirements of the pigs as defined by NRC (2012). These diets were fed in 4 phases from approximately 60 to 90, 90 to 150, 150 to 215, and 215 to 245 lb BW. Experimental diets were subsampled and samples were sent to a commercial laboratory (Ward Laboratories Inc., Kearney, NE) for analysis (DM, CP, fat, ash, Ca, and P) and subsamples were also shipped to another commercial laboratory (AIB International, Manhattan, KS) for dietary niacin concentrations. Pigs and feeders were weighed approximately every 14 d to determine ADG, ADFI, and F/G.

Carcass Measurements

On d 98, the heaviest barrow and gilt (determined visually) from each pen were marketed following normal farm procedures. Pigs were tattooed by gender and pen and transported to JBS Swift and Company (Worthington, MN) for processing and carcass data collection. Hot carcass weights were measured immediately after evisceration and each carcass was evaluated for percentage yield, backfat and loin depth. Percentage yield was calculated by dividing HCW by live weight obtained at the farm before transport to the abattoir. Fat depth and loin depth were measured with an optical probe (SFK; Herlev, Denmark) inserted between the 3rd and 4th ribs located anterior to the last rib at a distance approximately 2.8 in. from the dorsal midline. Fat-free lean index (FFLI) was calculated using NPPC (2000) guidelines for carcasses measured with the Fat-O-meater such that FFLI= ((15.31 + (0.51 × HCW, lb) – (31.277 × last rib fat thickness, in.) + (3.813 × loin muscle depth, in.))/HCW, lb.

Meat Quality

All meat quality was performed using the left side of the carcass. All pH measurements were collected using a pH meter (Model 9025, Hanna Instruments, Smithfield, RI) with a glass tip probe. The pH measurements were taken at three time points to evaluate the pH decline post-slaughter; 45 min, 3 h, and 21 h. At the 45 min and the 3 h time points, the probe was inserted into the longissimus dorsi (LD) between the 10th and 11th rib. Approximately 20.5 h postmortem, carcasses were fabricated for sample collection and additional analysis. A 15.7 in section of the LD was removed from the posterior end of the loin, individually labeled, and allowed to bloom for 30 min. After blooming, subjective color and marbling scores were determined by a trained evaluator using the 1 to 6 scoring system for color and the 1 to 5 scoring system for marbling (NPPC, 2000). In addition, the 21 h pH was recorded by again placing the probe into the LD at a central position across the sirloin face.

The LD was subsequently vacuum-packaged and transported on ice to the Kansas State University Meats Laboratory for subsequent analysis. Samples were stored at 39.2° F and aged for 10 d post-slaughter.

After aging, purge loss was measured by initially weighing the packaged LD, then removing the packaging and pat drying both the package and the LD sample. After weighing the dried package and LD sample, purge loss was calculated as a percentage of the original LD weight. Ultimate pH was then recorded by placing the probe into the LD at a central position across the sirloin face. Afterwards, 3 1-in.-thick boneless chops were fabricated from the anterior end of the loin. The 1st chop was trimmed to approximately 100 g of lean to estimate 24 h drip loss. These samples were bagged individually and were stored at 39.2 °F for 24 h after which samples were pat dried and reweighed to calculate 24 h drip loss as a percentage of original sample weight. The second LD chop was placed on a 1 S polystyrene tray (Dyne-A-Pak Inc., LAVAL, QC, Canada) and was overwrapped with a polyvinylchloride film (23,250 mL of O2/m2/24 h oxygen permeability/flow rate). The packages were placed in an open top retail display case (unit model DMF8, Tyler Refrigeration Corp., Niles, MI) at 35.6°F ± 3.6°F and were allowed to bloom for 45 min. After blooming, subjective color and marbling score were determined by 3 trained evaluators using the previously discussed scoring systems (NPPC, 2000). Afterwards objective color measurements of lean color were determined using a HunterLab Miniscan XE Plus spectrophotometer (Model 45/0 LAV, 2.54-cm-diameter aperture, 10° standard observer, Illuminant D65, Hunter Associates Laboratory, Inc., Reston, VA) to measure CIE L* (lightness), a* (redness), and b* (yellowness). The spectrophotometer was calibrated against a standard white tile (Hunter Associates Laboratory) and 2 locations of the lean surface of each sample were measured and averaged to determine the CIE L*, a*, and b* values. The third chop was frozen at -4 °F until subsampled with these subsamples being individually flash frozen using liquid nitrogen and then pulverized. Afterwards, 0.5 g of pulverized sample was weighed and niacin was extracted in solution using an acid hydrolysis technique discussed by the European Committee for Standardization (2009[4]). These extracted samples were analyzed in duplicate using HPLC analysis. Final loin niacin concentrations are expressed as mg/lb of tissue.

Barn Environmental Monitoring

Three temperature loggers (LogTag Recorders, New Zealand) were placed in the barn in order to collect daily ambient temperature and relative humidity. Readings were recorded hourly throughout the day on each logger and an average hourly temperature and humidity were determined. Hourly data was used to calculate daily high, low, and average values (Figure 1).

Pig Temperature Monitoring

On d 57, 58 and 59 (August 8, 9, 10), a randomly selected barrow and gilt within each pen were used to determine pig rectal and body temperatures throughout the day. On each collection day, rectal temperatures were collected using electronic thermometers (Sure Temp Model 692; Welch Allyn, San Diego, CA) and skin temperatures were taken on the top of the shoulder and rump using an infrared dual laser thermometer (Model 42512; Extech Instruments Corporation, Waltham, MA). Temperatures were collected from the same pigs within each pen at 06:00, 09:00, 12:00, 15:00, and 18:00 during the three consecutive collection days.

[4] European Committee for Standardization. 2009. Foodstuffs – Determination of niacin by HPLC. Tech. Bull. No. 15652. British Standards Institution, United Kingdom.

Statistical Analysis

Data were analyzed as a randomized complete block design using the PROC MIXED procedure of SAS (SAS Institute, Inc., Cary, NC). Linear and quadratic polynomial contrasts were used to determine the effects of increasing nicotinic acid. Pen served as the experimental unit for growth performance. Carcass data were analyzed as a split plot design with pig as the experimental unit to evaluate the effects of gender. Temperature data were also analyzed as a split plot design to evaluate the effects of gender using repeated measures with time × day interactions as the repeated variable and pig as the subject. Additionally, a Toeplitz covariance model was used for the temperature analysis. This covariance structure assumes that pairs of within-subject errors separated by a common lag share the same correlation and it provided the best fit of the temperature data (as measured by smaller AIC, AICC, and BIC values).

Results:

Diet Analysis

Experiment diets were analyzed for niacin content at a commercial laboratory (AIB International, Manhattan, KS). Diets formulated to contain 14, 172, 331, and 490 mg/lb were determined to contain niacin concentrations of 18, 117, 256, and 564 mg/lb (Table 2), respectively.

Growth Performance

For growth performance, dietary niacin did not influence growth from d 0 to 28 ($P > 0.05$; Table 3). However, from d 28 to 55, ADG tended (linear; $P = 0.10$) to increase and ADFI increased (linear; $P = 0.02$) with increasing dietary niacin. From d 55 to 86 pigs fed increasing dietary niacin had increased (quadratic; $P = 0.01$) ADG and tended (quadratic; $P = 0.10$) to have increased ADFI with the greatest values for pigs fed diets with 331 mg/lb of added niacin. Additionally, during the same period, pigs fed increasing dietary niacin also had improved feed conversion rates (quadratic; $P = 0.01$) with the best value at 331 mg/lb. Interestingly, from d 86 to 98 increasing dietary niacin tended to decrease ADG (linear; $P = 0.10$) although ADFI was still increased with increased dietary niacin (linear; $P = 0.01$). As a result, feed efficiency was worsened (linear; $P = 0.02$). Overall from d 0 to 98, ADG and F/G were not influenced by increasing dietary niacin ($P > 0.17$), but ADFI tended to increase with increasing dietary niacin (linear; $P = 0.07$).

Carcass Characteristics

No dietary niacin × gender interactions were observed for carcass trait data. Additionally, carcass traits were not influenced ($P > 0.05$; Table 4) by dietary niacin; however, barrows had heavier final live weights, HCW, and increased yield percentages ($P < 0.03$) compared to gilts. Alternatively, gilts had lower BF, increased loin depth, and higher fat-free lean indexes ($P = 0.01$) compared to barrows.

Meat Quality

Forty-five min pH was reduced (linear; $P = 0.01$) with increased dietary niacin. A dietary niacin × gender interaction ($P = 0.01$) was observed for the 3 h pH measurement because barrows fed 14 and 331 mg/lb niacin had lower pH values compared to gilts fed the same diets, while barrows fed 172 and 490 mg/lb had higher pH values than gilts fed the same diets. This was the only interaction observed for meat quality data. Twenty-one h

pH was reduced (linear; $P = 0.01$) with increasing dietary niacin. Ultimate pH was not altered ($P > 0.11$) by dietary niacin but barrows ($P = 0.02$) had higher ultimate pH compared to gilts. Subjective color and marbling scores of loins and boneless chops were not influenced ($P > 0.22$) by dietary niacin. Barrows had higher ($P = 0.04$) boneless chop color and marbling scores and tended ($P = 0.08$) to have higher loin marbling scores compared to gilts. Purge loss and 24 h drip loss were not different ($P > 0.18$) among dietary niacin treatments or genders. In terms of objective lean color scores, increasing dietary niacin increased (linear; $P < 0.05$) a* and b* values. Boneless chop niacin concentrations were not influenced ($P > 0.56$) among dietary niacin treatments or gender.

Barn Environment and Pig Temperature

Daily average temperatures within the barn ranged from 63.8 to 85.5 °F (Figure 1) throughout the length of the study, meanwhile daily low temperatures ranged from 59.9 to 81.0 °F, and daily high temperatures ranged from 66.1 to 93.3 °F. Daily average humidity ranged from 44.9 to 85.5% relative humidity with low daily humidity measurements ranging from 26.3 to 76.0%, and daily high humidity ranging from 58.2 to 91.4%. In general, temperature was cooler than expected for the facility compared to the expected seasonal increases associated with summer months and humidity was variable throughout the length of the study.

A time × day interaction ($P < 0.01$; Figure 2) was observed for rectal temperatures; however no dietary niacin × gender interactions were found within specific time × day collection points. At 6:00 on d 1 increasing dietary niacin increased (linear; $P = 0.02$) rectal temperature; however, at 12:00 on d 1 increasing niacin decreased (quadratic; $P = 0.03$) rectal temperatures with pigs fed 172 mg/lb having the lowest temperature. Additionally, barrows had higher rectal temperatures at 15:00 and 18:00 on d 1 and at 15:00 on d 3. Overall the inconsistent differences in rectal temperatures across dietary treatments suggest dietary niacin supplementation did not biologically impact core body temperatures during the collection period. This conclusion disagrees with previous research conducted in dairy cows which concluded that supplementing high dosed of niacin reduced rectal and vaginal temperatures and increased evaporative heat loss.

For shoulder and rump skin temperatures, time × day interactions (Figure 3 and 4; $P < 0.01$) were also observed. Shoulder skin temperatures were increased (linear, $P = 0.05$) at 6:00 on d 1 with increased dietary niacin, and gilts had higher ($P = 0.04$) shoulder skin temperatures compared to barrows. Shoulder and rump temperatures decreased (quadratic; $P < 0.04$) with increased dietary niacin at 9:00 on d 1 with pigs fed 172 mg/lb having the lowest skin temperatures. On d 2 at 6:00, a gender × dietary niacin interaction ($P = 0.03$) was observed for shoulder skin temperature because barrows fed 331 mg/lb niacin had higher temperatures compared to gilts fed the same diet, but barrows fed 14, 172, or 490 mg/lb niacin had lower temperatures compared to gilts fed the same diets. Also on d 2 at 9:00, decreased (linear; $P = 0.05$) skin shoulder and rump temperatures were observed for pigs fed increasing dietary niacin. On d 3 at 15:00, increasing ($P = 0.05$) skin temperatures were observed for pigs fed increasing dietary niacin with pigs fed 331 mg/lb having the highest temperatures. Similar to rectal temperature data, it appears that dietary niacin supplementation did not alter skin temperatures consistently over the collection period.

Table 1. Diet composition (as-fed basis)[1]

Item	Phase 1	Phase 2	Phase 3	Phase 4
Corn[2]	55.19	60.14	64.56	66.76
Soybean meal (46.5% CP)	22.47	17.68	13.40	11.36
Corn DDGS[3]	20.00	20.00	20.00	20.00
Limestone	1.10	1.20	1.15	1.05
Salt	0.35	0.35	0.35	0.35
Dicalcium phosphate	0.15	---	---	---
DL-methionine	0.01	---	---	---
L-threonine	0.05	0.02	---	---
Biolys (lysine sulfate)	0.51	0.44	0.39	0.33
Phytase[4]	0.02	0.02	0.02	0.02
Vitamin premix[5]	0.08	0.08	0.08	0.08
Trace mineral premix[6]	0.07	0.07	0.05	0.05
Total	100.0	100.0	100.0	100.0
Calculated analysis				
Standardized ileal digestible (SID) amino acids,%				
Lysine	1.06	0.91	0.78	0.70
Isoleucine:lysine	68	70	73	76
Methionine:lysine	30	32	35	37
Met & cys:lysine	56	60	65	70
Threonine:lysine	62	62	63	66
Tryptophan:lysine	18.0	18.0	18.0	18.5
Valine:lysine	77	82	86	91
Total lysine, %	1.24	1.08	0.94	0.85
CP, %	21.2	19.2	17.5	16.6
ME, kcal/lb	1,505	1,507	1,510	1,512
SID Lysine:ME, g/Mcal	3.20	2.74	2.34	2.10
Ca, %	0.53	0.52	0.49	0.44
P, %	0.45	0.40	0.38	0.37
Available P, %	0.30	0.27	0.26	0.26
Analyzed dietary concentrations[7]				
Dry Matter, %	90.80	90.14	90.30	89.75
CP, %	21.9	19.7	17.6	18.3
Fat, %	4.18	4.03	4.10	4.48
Ash, %	4.63	4.53	3.82	3.93
Ca, %	0.68	0.74	0.55	0.50
P, %	0.43	0.39	0.35	0.39

[1] Diets were fed in meal form during the experiment. Diets were fed in 4 phases from approximately 60 to 90, 90 to 150, 150 to 215, and 215 to 245 lb BW.

[2] The 4 dietary treatments were obtained by replacing corn in each diet with nicotinic acid (Lonza, Allendale, NJ) to achieve total niacin concentrations of 14, 172, 331, and 490 mg/lb of complete feed.

[3] Dried distillers grains with solubles.

[4] Optiphos 2000 (Enzyvia, Sheridan, IN) provided 363.2 phytase units (FTU)/lb, with a release of 0.12% available P.

[5] Provided per pound of premix: 3,200,000 IU vitamin A; 500,000 IU vitamin D_3; 16,000 IU vitamin E; 1,600 mg vitamin K; 2,800 mg riboflavin; 10,000 mg pantothenic acid; 18,000 mg niacin; 12 mg vitamin B_{12}.

[6] Provided per pound of premix: 50 g Zn from zinc sulfate; 50 mg Fe from iron sulfate; 15 g Mn from manganese oxide; 7.5 g Cu from copper sulfate; 150 mg I from calcium iodate; and 136 mg Se from sodium selenite.

[7] Analysis performed by Ward Laboratories Inc. (Kearney, NE); means represent the average of 4 samples within each dietary phase.

Table 2. Analyzed dietary niacin concentrations[1]

	Dietary niacin, mg/lb			
Formulated	14	172	331	490
Analyzed	18	117	256	564

[1] Analysis performed by AIB International (Manhattan, KS). Means represent the average of duplicate samples that were obtained by pooling samples across dietary phases within experimental treatments.

Table 3. Effects of increasing dietary niacin on finishing pig growth performance[1]

	Dietary niacin, mg/lb[2]					*Probability, P <*	
Item	14	172	331	490	SEM	Linear	Quadratic
d 0 to 28							
ADG, lb	1.81	1.80	1.78	1.82	0.02	0.74	0.29
ADFI, lb	3.43	3.53	3.53	3.50	0.06	0.39	0.83
F/G	1.90	1.95	1.98	1.92	0.02	0.38	0.62
d 28 to 55							
ADG, lb	1.77	1.83	1.84	1.85	0.02	0.10	0.54
ADFI, lb	4.36	4.60	4.61	4.54	0.05	0.02	0.52
F/G	2.46	2.52	2.51	2.45	0.03	0.81	0.96
d 55 to 86							
ADG, lb	1.85	1.83	1.93	1.83	0.03	0.72	0.01
ADFI, lb	5.43	5.60	5.71	5.70	0.05	0.71	0.10
F/G	2.79	2.83	2.73	2.79	0.03	0.37	0.01
d 86 to 98							
ADG, lb	1.75	1.72	1.60	1.66	0.05	0.10	0.25
ADFI, lb	5.43	5.60	5.71	5.70	0.08	0.01	0.82
F/G	3.14	3.28	3.61	3.44	0.11	0.02	0.15
d 0 to 98							
ADG, lb	1.81	1.81	1.82	1.81	0.01	0.40	0.50
ADFI, lb	4.47	4.59	4.63	4.56	0.04	0.07	0.71
F/G	2.48	2.54	2.54	2.51	0.02	0.17	0.89
BW, lb							
d 0	59.4	59.4	59.4	59.4	1.1	1.00	0.98
d 28	110.2	110.0	109.5	110.6	1.4	0.90	0.78
d 55	158.6	159.6	159.7	161.0	1.6	0.26	0.73
d 86	216.8	217.3	219.8	218.3	1.6	0.29	0.35
d 98	239.3	238.1	239.3	239.3	1.5	0.85	0.60

[1] A total of 1,232 pigs (PIC 337 × 1050; initially 59.4 lb) were used in a 98 d study to determine the influence of increasing dietary niacin concentrations on growth performance. There were 11 pens per treatment and 28 pigs per pen.

[2]Nicotinic acid was used as the source of added niacin to achieve dietary treatment concentrations.

Table 4. Main effects of gender and dietary niacin concentration on carcass traits and meat quality measurements[1]

									Probability, P		
	Gender			Dietary niacin, mg/lb						Niacin	
Item	Barrow	Gilt	SEM	14	172	331	490	SEM	Gender	Linear	Quadratic
Carcass traits											
Live wt, lb	274.7	268.8	2.0	271.1	267.3	273.3	275.3	2.7	0.02	0.11	0.23
HCW, lb	201.1	194.1	1.4	196.5	195.5	199.5	198.9	2.0	0.01	0.19	0.26
Yield, %	73.3	72.4	0.4	72.7	73.1	73.1	72.3	0.5	0.03	0.48	0.81
Loin depth, in^2	2.60	2.73	0.03	2.63	2.69	2.67	2.68	0.05	0.01	0.59	0.56
BF, in^2	0.68	0.56	0.02	0.62	0.62	0.62	0.60	0.03	0.01	0.68	0.90
FFLI, %[2,3]	53.1	55.3	0.4	54.1	54.1	54.1	54.4	0.05	0.01	0.68	0.90
pH											
45 min	6.47	6.49	0.05	6.66	6.51	6.41	6.35	0.14	0.86	0.01	0.95
3 h	6.28	6.40	0.03	6.39	6.30	6.37	6.28	0.04	0.01	0.19	0.09
21 h	5.95	5.92	0.01	5.99	5.93	5.92	5.91	0.02	0.11	0.01	0.51
Ultimate	5.86	5.80	0.02	5.87	5.81	5.84	5.80	0.03	0.02	0.11	0.17
Meat quality											
Loin color[4]	3.47	3.33	0.08	3.43	3.34	3.44	3.39	0.11	0.15	0.92	0.47
Loin marbling[4]	1.50	1.34	0.07	1.43	1.27	1.42	1.55	0.10	0.08	0.22	0.43
Chop color[4]	3.04	2.83	0.07	3.05	2.83	2.93	2.92	0.11	0.04	0.54	0.38
Chop marbling[4]	1.70	1.55	0.05	1.63	1.61	1.57	1.69	0.08	0.04	0.65	0.56
Purge loss, %	1.39	1.60	0.14	1.45	1.40	1.51	1.62	0.21	0.27	0.47	0.85
24 h drip loss, %	2.88	3.04	0.26	2.97	2.83	3.42	2.62	0.38	0.63	0.76	0.18
L*	53.41	54.35	0.55	53.12	54.67	53.56	54.16	0.82	0.21	0.54	0.21
a*	18.61	18.61	0.26	18.20	18.30	18.89	19.05	0.39	0.99	0.05	0.58
b*	16.54	16.69	0.27	16.05	16.45	16.88	17.09	0.40	0.69	0.04	0.89
Loin niacin, mg/lb	52.23	52.39	2.53	53.45	49.54	50.20	56.04	3.57	0.96	0.56	0.97

[1] A total of 88 pigs (2 per pen; 1 barrow and 1 gilt) were used to determine the effects of gender and dietary niacin concentration on carcass traits and meat quality

[2] Adjusted with HCW as a covariate.

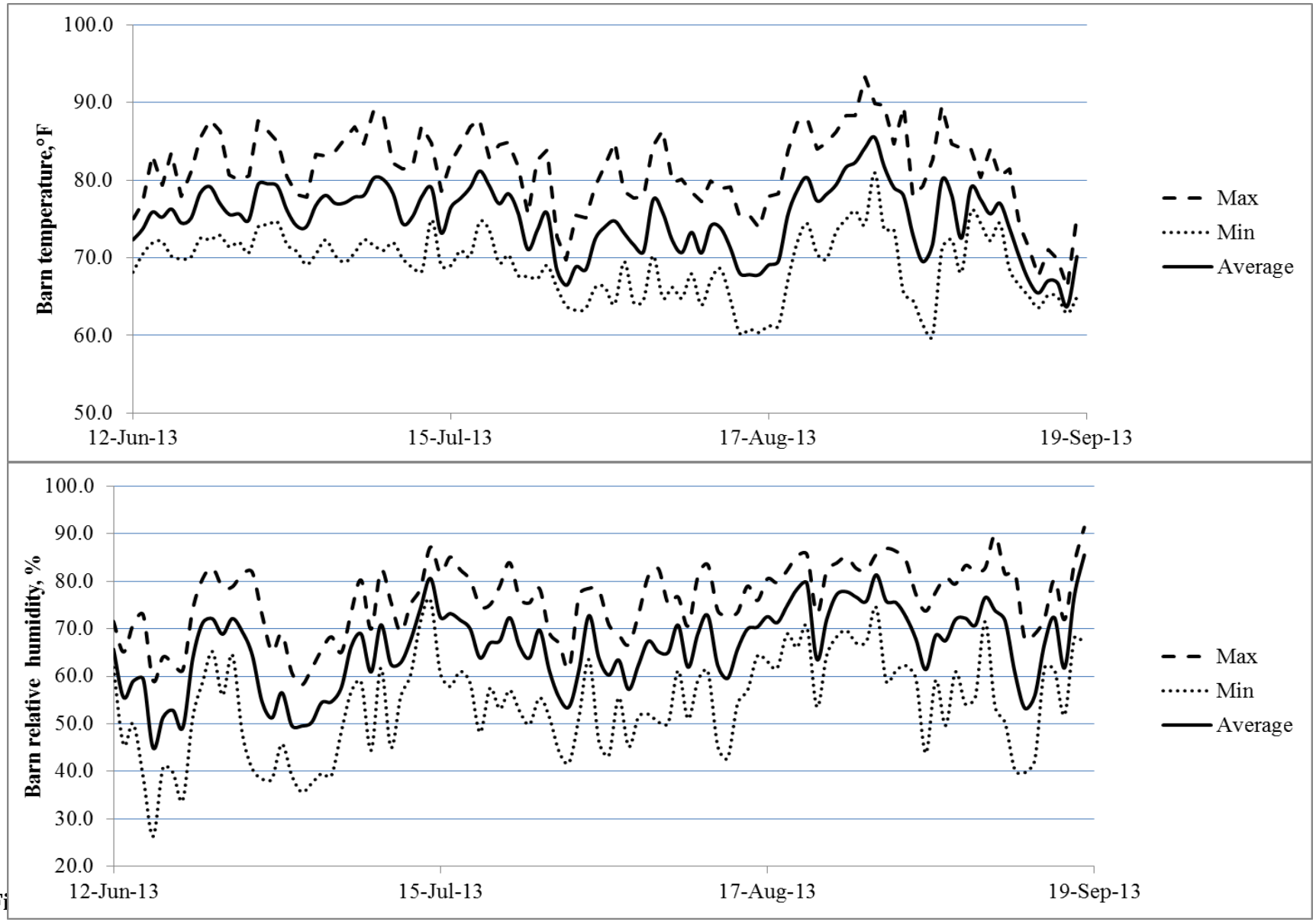
[3] Fat-free lean index (FFLI) was calculated using NPPC (2000) guidelines for carcasses measured with the Fat-O-Meater such that FFLI = (15.31 + (00.51 × HCW, lb) - (31.277 × last rib fat thickness, in.) + (3.813 × loin muscle depth, in.))/ HCW, lb.

[4] Subjective color scores were conducted using a scale of 1 to 5, and marbling scores were conducted using a numeric scale of 1 to 5 both are previously described by NPPC (2000).

Table 5. Interactive effects of gender and dietary niacin on carcass pH.[1]

	Dietary niacin treatment, mg/lb									
	14		172		331		490			*Probability, P <*
Item	Barrow	Gilt	Barrow	Gilt	Barrow	Gilt	Barrow	Gilt	SEM	Interaction
pH										
45 min	6.48	6.83	6.59	6.42	6.51	6.32	6.31	6.39	0.12	0.08
3 h	6.28	6.50	6.32	6.28	6.21	6.54	6.30	6.27	0.06	0.01
21 h	5.98	6.00	5.96	5.89	5.91	5.93	5.96	5.87	0.03	0.09
Ultimate	5.90	5.84	5.84	5.77	5.91	5.77	5.80	5.79	0.05	0.60

[1] A total of 88 pigs (2 pigs per pen; 1 barrow and 1 gilt) were used to determine the effects of gender and dietary niacin on carcass pH.


100.0
90.0
80.0
70.0
60.0
50.0
Barn temperature,°F
12-Jun-13
15-Jul-13
17-Aug-13
19-Sep-13
Max
Min
Average
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
Barn relative humidity, %
12-Jun-13
15-Jul-13
17-Aug-13
19-Sep-13
Max
Min
Average

Fi

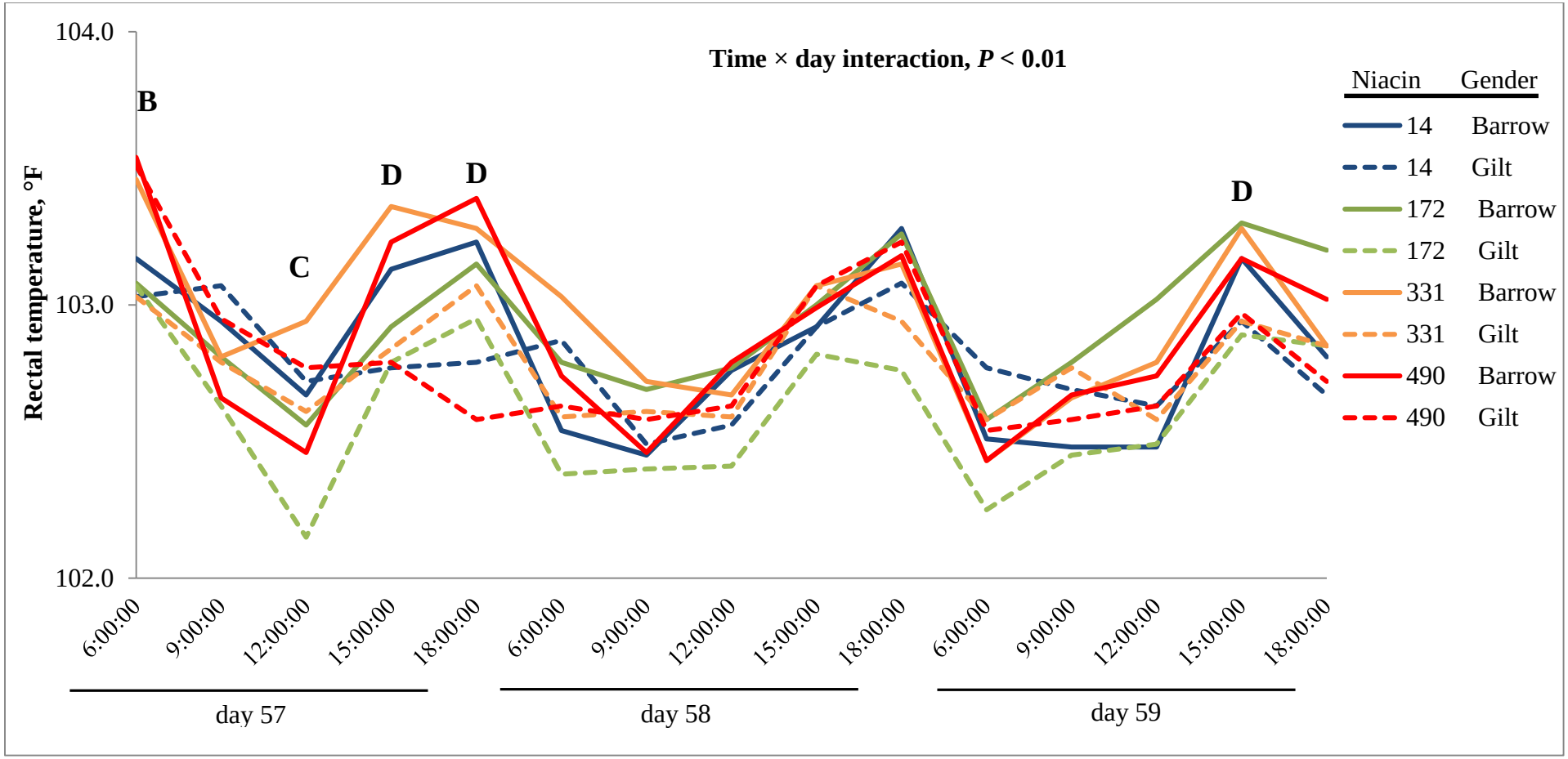


Figure 2. Rectal temperatures (°F) during d 57, 58, and 59 of the study. Temperatures were collected from 1 barrow and 1gilt per pen. Superscripts denote differences ($P < 0.05$): [B] linear dietary niacin effect; [C] quadratic dietary niacin effect; [D] gender effect.

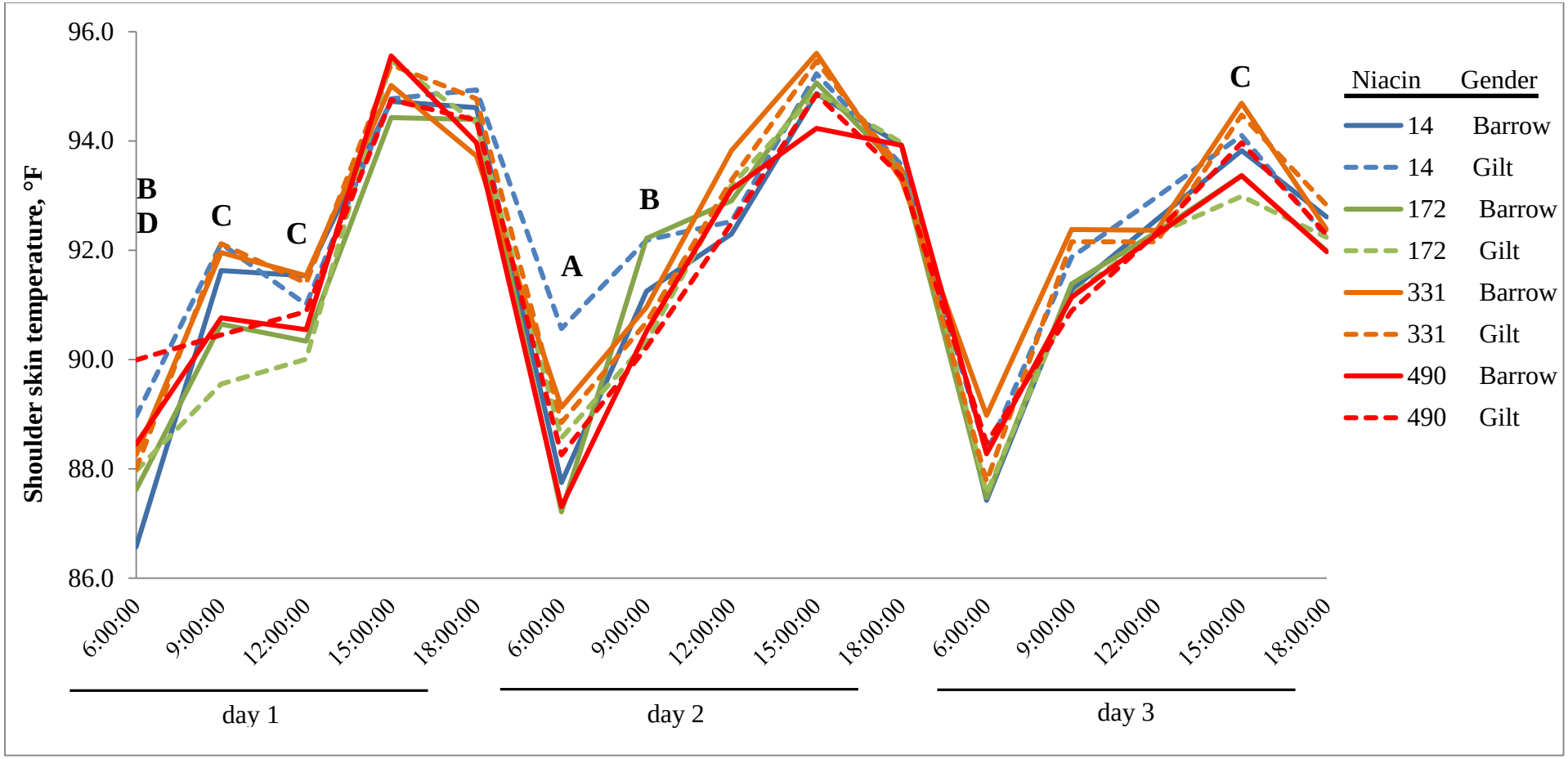


Figure 3. Shoulder skin temperatures (°F) during d 57, 58, and 59 of the study. Temperatures were collected from 1 barrow and 1gilt per pen using an infrared dual laser thermometer. Superscripts denote differences ($P < 0.05$): [A] dietary niacin × gender interaction; [B] linear dietary niacin effect; [C] quadratic dietary niacin effect; [D] gender effect.

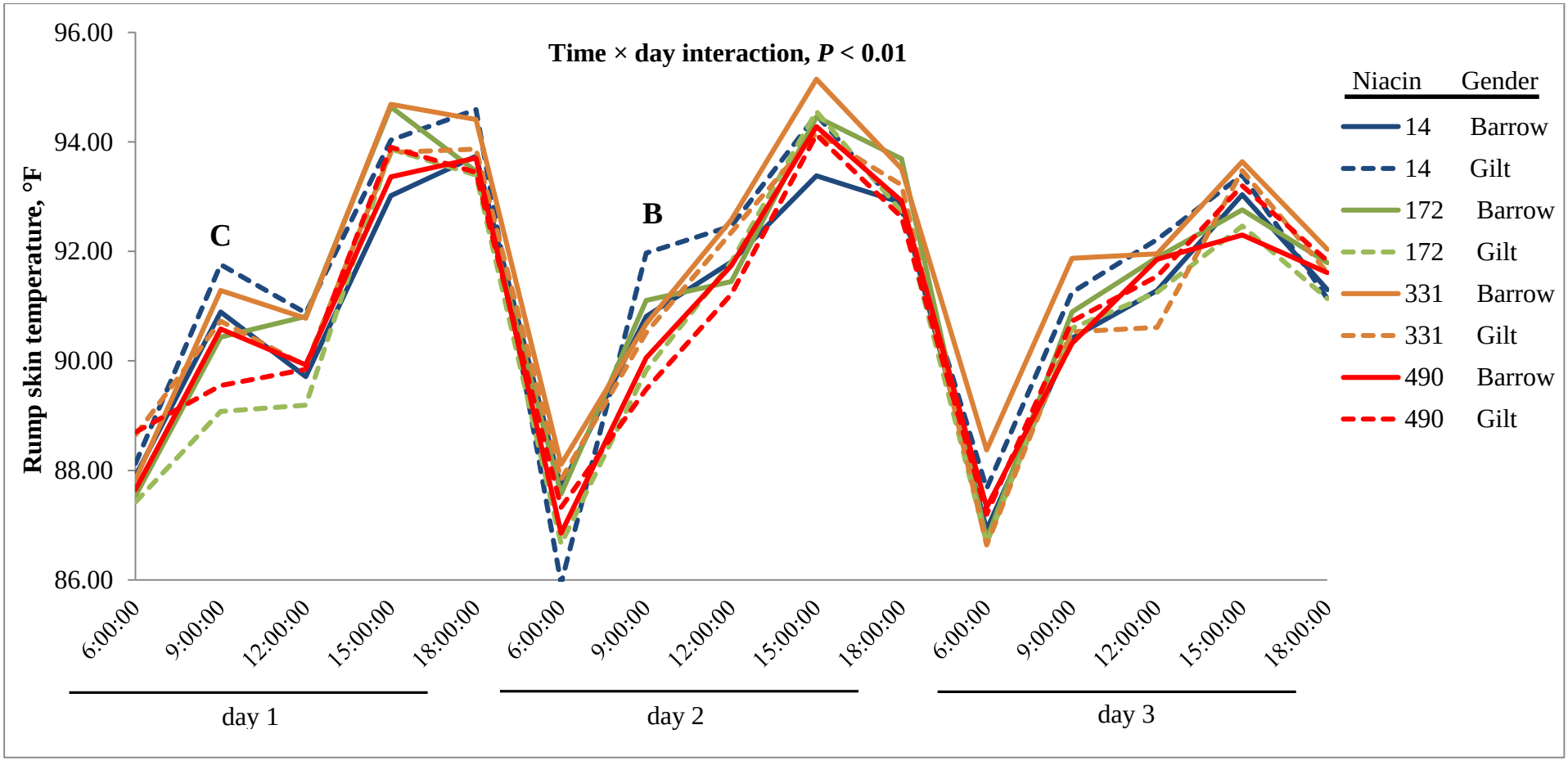


Figure 4. Rump skin temperatures (°F) during d 57, 58, and 59 of the study. Temperatures were collected from 1 barrow and 1gilt per pen using an infrared dual laser thermometer. Superscripts denote differences ($P < 0.05$): [B] linear dietary niacin effect; and [C] quadratic dietary niacin effect.

Discussion:

The current study suggests that additional supplementation of niacin above the animal's requirement (NRC, 2012[5]) does not influence ADG or F/G. Nevertheless, our data is in agreement with that of Real et al. (2002) who concluded that 6 to 24 mg/lb of added niacin are needed to maximize gain and feed efficiency (14 mg/lb used in our study). It should be noted that the objective of this experiment was not to evaluate the niacin requirement, as the levels were 12 to 33 times requirement the requirement estimates of the pig for the increasing levels used in this study.

Overall, the current study suggests that supplementation of niacin from 14 to 490 mg/lb does not drastically impact pork quality. This contrasts with previous meat quality research by Real et al. (2002) who observed improved color and pH with increasing niacin supplementation up to 249 mg/lb. One reason for the difference in results may be due to the fact that carcasses in the current study underwent chilling in a blast chiller which may have mitigated some effects on meat quality that were previously observed during a longer chilling period. In a recent study, Khan et al. (2013[6]) concluded that feeding 340 mg/lb nicotinic acid to intact boars resulted in an increase in muscle fiber switching from glycolytic type II fibers to oxidative type I fibers. The authors hypothesized that this may lead to an increase in dark, firm and dry pork. The current study would contrast that conclusion given that subjective color was not different among niacin treatments and that pH decline was actually enhanced by niacin supplementation.

The study was designed to test the influence of increasing niacin during heat stress. Unfortunately the barn environmental conditions did not achieve the expected high temperatures and humidity as documented in previous year's summer months. As a result, the degree of seasonal heat stress observed during this study was less than anticipated which may have influenced the lack of response to increasing dietary niacin. Furthermore, it may support why inconsistent responses to rectal temperatures as well as shoulder and rump skin temperatures were observed. Ultimately this data indicates that when the daily average temperature ranged from 63.8 to 85.5 °F and daily average humidity ranged from 44.9 to 85.5% increasing niacin to levels significantly above the pig's requirement estimate did not elicit benefits in growth performance, carcass composition or quality, or rectal and body temperatures.

[5] NRC. 2012. Nutrient requirements of swine, 11th rev. ed. Natl. Acad. Press, Washington, DC.
[6] Khan, M., R. Ringseis, F. Mooren, K. Kruger, E. Most, and K. Eder. 2013. Niacin supplementation increases the number of oxidative type I fibers in skeletal muscle of growing pigs. BMC Veterinary Research 9:177.