Title: Effect of Seasonal Environment, On-Farm Handling Intensity, Transport Stocking Density, and Time in Lairage on Digestive Tract Temperature and Stress Hormone Level of Market Pigs – **NPB# 04-022**

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Abstract: The present series of studies were conducted to evaluate three seasonal environments: temperate (**TMP**), cold stress (**CS**), and heat stress (**HS**), two on-farm handling intensities: conventional (**CONV**) and passive (**PAS**), two transport stocking densities: tight (TSD) and loose (LSD), and two lairage lengths: 45 min and 3 h, on digestive tract temperature and blood plasma cortisol levels. Market hogs at an average live weight of 125 kg were harvested at three representative environmental situations: TMP, 6 to 13˚C, (n =111); CS, – 9 to 0˚C (n =113); and HS, 22 to 35˚C (n =112). At 16 h prior to harvest, a computer-activated temperature logging device (Ibutton), was placed down the throat of the market hogs. Half of all hogs were randomly subjected to PAS handling and the other half CONV handling, with each group being loaded on trailers with identical dimensions. As each respective handling group was loaded, approximately half of the pigs were allotted to a tight loading density (0.4 m^2/per pig) and the other portion to a loose loading density (0.5 m^2/per pig). After transport to the harvest facility, half of the test animals within each trailer were randomly allocated to the 45 min or 3 h lairage treatment. Blood collection for subsequent cortisol analysis was made at exsanguination. Ibuttons were collected from the viscera at harvest. Prior to handling, CS pigs had higher digestive tract temperatures ($P < 0.04$) than pigs from the other two harvests. However, during handling, CONV handled pigs from the HS harvest displayed no difference ($P > 0.40$) in digestive tract temperature compared to PAS handled pigs from the CS harvest. This suggests that the added activity during CONV handling accelerated the body metabolism of the HS pigs, raising their digestive tract temperature. During lairage, pigs from the HS harvest had higher ($P = 0.001$) digestive tract temperatures than pigs from the TMP harvest, which had higher ($P < 0.03$) temperatures than CS harvested pigs. This suggests the activity associated with the re-establishment of dominance in lairage accelerated the metabolism of the HS pigs. Pigs subjected to the 3 h lairage tended ($P = 0.06$) to have higher digestive tract temperatures than pigs subjected to the 45 min lairage. Pigs from the HS harvest given a TSD had higher ($P < 0.021$) cortisol levels than TMP and CS pigs at a TSD, as well as

HS and CS pigs given a LSD, suggesting a TSD exacerbates heat stress. Pigs from the HS harvest given 3 h of lairage had higher *(P* < 0.011) cortisol levels than TMP pigs given 3 h of lairage; and, HS and TMP pigs given 3 h of lairage had higher ($P < 0.011$) cortisol levels than HS and TMP pigs given 45 min of lairage, suggesting a 3 h lairage exacerbates heat stress. The results of this study indicate that during times of heat stress, pigs should be kept in lairage less than 3 h to improve animal welfare. Further study is necessary to determine if pigs maintained in lairage longer than 3 h marginalizes the affects of the seasonal heat stress environment.

Introduction: Animal agriculture, as it relates to the production practices of our nation's meat-animal industries, is often portrayed to the public in a negative manner. The good stockmanship practices exhibited by most producers goes unnoticed, where the poor judgment exhibited by a select few individuals often becomes sensationalized and reflects poorly upon the entire industry. To counteract this public perception, improved husbandry and stewardship practices have been emphasized to producers over the past two decades.

The welfare of an animal is "*its state as regards its attempts to cope with its environment*" (Broom, 1991). Productive welfare implies a state of well-being of an animal's health and environment that is conducive to an animal performing up to its genetic predisposition (Warriss, 1998). The improvement of an animal's overall welfare has been associated with improved animal production (Hemsworth and Coleman, 1998; Grandin, 2003). Specifically within pork production, the stress associated with transport, handling, and lairage of market weight swine prior to harvest has been documented to impact not only the welfare of the given animals, but ultimately producer profitability (Grandin, 1993; Den Ouden et al., 1997).

Extensive research has been conducted with pigs on the effects of stocking density, length of transport, and time in lairage on stress metabolites and lean quality. Additionally, it is well established that stressful handling immediately prior to harvest has dramatic effects on body metabolism, stress hormone profiles, and lean quality (D'Souza et al., 1998; Hambrecht et al., 2005). With that in mind, U.S. pork processors have begun to demand that their livestock personnel be trained to handle animals patiently and calmly to uphold governmental and private industry animal welfare requirements and to minimize stress immediately prior to harvest. Since the issue of pre-harvest animal handling at the packing plant is being addressed by the industry itself, it could be argued that evaluating stress immediately prior to harvest is no longer justified in this country. That said, little is known about the effects of on-farm handling intensity and its residual effects on body metabolism and stress metabolites during transport and lairage.

Core body temperature serves as an indirect indicator of metabolic rate (Webb, 1995). The maintenance of core body temperature is accomplished through the balance of heat production and heat loss. During the stress of transport, pigs are often near their upper threshold of thermal tolerance (Lambooij and van Putten, 1993). The temperatures within the digestive tract of live animals should produce values representative of core body temperature. (D. Spiers, Personal Communication). Hence, suggesting that a non-invasive assessment of digestive tract temperature could prove to be a valuable tool relative to the improvement of swine welfare during handling, transport, and lairage.

Project Objectives:

a) Determine the effect of seasonal environment, on-farm handling intensity, transport stocking density, and length of lairage time on temperature within the digestive tract of market hogs.
b) Evaluate blood cortisol at exsanguination as objective assessments of stress associated with harvest.
c) Determine the effectiveness of evaluating temperature within the digestive tract as an indicator of animal welfare.

Methods and Materials:

Sensor Ingestion

Market hogs at an average live weight of 125 kg were harvested at three representative environmental situations: temperate (**TMP**) 6 to 13˚C, (n = 111), cold stress (**CS**) – 9 to 0˚C (n = 113), and heat stress (**HS**) 22 to 35˚C (n = 112). Approximately 16 h prior to harvest, all pigs were withheld from conventional feeding. Approximately 1 h later, pigs were individually snared by a conventional hog snare, and then ear tagged for treatment identification and tattooed for carcass identification. At the same time, a computer-activated temperature logging device marketed as an Ibutton (Dallas Semiconductor Corp. Dallas, TX www.ibutton.com) was placed within a conventional small balling gun, placed within the pig's mouth, and the plunger was depressed. Following Ibutton ingestion, pigs were allowed to rest to recover from snaring prior to transport to the abattoir. The Ibuttons were calibrated to log temperature at 10 min intervals.

Handling During Loading

The experimental design is diagrammed in Appendix A. Loading for transport was initiated at 0400 h. Half of all pigs (n = 56) were randomly subjected to passive (**PAS**) handling and the other half conventional (**CONV**; n = 56) handling. Each group was loaded on individual trucks with identical trailer dimensions. The PAS handled pigs were loaded first. That trailer then waited at the loadout facility for the CONV handled pigs to be loaded. The PAS handled pigs were moved at a moderate to slow handling speed, with little to no handler vocalization, and limited utilization of paddles or boards, and absolutely no electric prod usage. The CONV handled pigs were subjected to a more rapid-paced handling, extensive vocalization by handlers, and extensive physical manipulation via hog paddles and boards, as well as selective utilization of electric prods. The CONV handling treatment was indicative rapid, more aggressive handling, yet remained conscious of the pig's welfare. Individual pig ear tags were recorded for treatment identification.

Stocking Density

As each respective handling group was loaded, approximately half of the pigs were allotted to a tight stocking density (**TSD**) within the trailer (0.4 m^2 per animal) and the other subjected to a more restful, loose stocking density (**LSD**), allowing all animals to lie down (0.5 m^2 per animal). Loading density specifications were modified from Lambooij and van Putten (1993). Both trailers were loaded with the same proportions and location within the trailer for each stocking density. In accordance to trailer dimensions, non-test animals (n = 4) were added to each trailer to insure proper stocking densities (Appendix B). At the conclusion of loading, both trailers contained 60 market hogs with 56 from each trailer being test pigs. Ear tags were recorded for stocking density treatment identification.

Unloading and Lairage

Following a 2.5 h trip to a commercial pork processing facility (Tyson Foods, Columbus Junction, IA), the passively handled pigs (the first trailer loaded) were unloaded immediately upon arrival. Half of the test pigs within each trailer (n = 56) were randomly allocated to one of two lairage treatments, 45 min or 3 h. Foreign pigs were never commingled into lairage pens. Pigs were given free access to water during lairage. Ear tags were recorded for lairage treatment identification. All pigs were subjected to handling by the researchers during unloading and by packing plant personnel for the walk to the stunning chute. All pigs were subjected to humane head-to-heart electrical stunning procedures.

Post-Mortem Measurements

At exsanguination, blood was collected from all pigs in pre-numbered tubes. Ear tag number and sequence was recorded. Following humane harvest and evisceration, the viscera was inspected for retrieval of the Ibuttons. A stud finder with a metal scan setting (Zircon Corp., Campbell, CA) was utilized to expedite object retrieval. Ibuttons (n = 247 of 336) were recovered for downloading of temperature data onto a personal computer after returning to the University of Missouri. All carcass composition parameters were assessed from the right carcass side. Midline last lumbar and last rib backfat measurements were made with a stainless steel carcass ruler in the carcass cooler. At the harvest floor grading station, hot carcass weight was recorded. Additionally, Animal Ultrasound Services (AUS), Carcass Value Technology System (Animal Ultrasound Services Inc., Ithaca, NY) was used to evaluate average fat depth and loin muscle depth (average depth from the 9th to 11th rib) for the calculation of percent muscle using the NPPC (2000) formula.

Blood Serum Analysis of Cortisol

The day following blood collections, samples were centrifuged at 2,500 X g for 45 min. After centrifugation, serum was pipetted from tubes, placed in 48 well plates (5 mL/well; ABgene, Inc., Rochester, NY) and stored at -20°C until analysis. Samples were allowed to thaw for 24 h prior to analysis. For the analysis of cortisol levels, 25 ul of serum was assayed in duplicate using the procedures described by the technical manual from Diagnostic Systems Laboratories (Webster, TX) and previously validated as described by Wise et al. (2000). The limit of assay sensitivity was 50 pg, and interassay variation was 8.5%. Values were reported in ng/mL.

Statistical Analysis

All assessments of digestive tract temperature, carcass traits, and blood serum cortisol levels were evaluated using ordinary least squares (PROC GLM, SAS Inst., Inc., Cary, NC). Ibutton temperatures from individual animals were averaged for four time periods representing pre-treatment rest (0245 to 0359 h), loading (0400 to 0530 h), transport (0531 to 0800 h), and lairage (0801 to exsanguination). Average Ibutton temperature data was terminated post-exsanguination when the recorded digestive tract temperature significantly differed from the previous temperature recorded. Average digestive tract temperature during time period of assessment was utilized as the dependent variable. Seasonal environment (harvest date), on-farm handling intensity, stocking density, and lairage time were utilized as fixed effects for digestive tract temperature and blood serum cortisol levels. Harvest date was the only fixed effect used in the assessment of carcass traits. Additionally, tube replicate was utilized as a fixed effect for cortisol analysis and F-tests for all main and interactive effects were not statistically different ($P > 0.480$).

Average digestive tract temperatures were evaluated via four independent analyses only utilizing fixed effects which would have impact upon responses. Least squares means were calculated for main and interactive effects and separated statistically using pair-wise *t*-tests (P-DIFF option of SAS) when a significant ($P < 0.05$) F-test was detected.

Results & Discussion:

Carcass Composition

Pigs from the TMP harvest had heavier ($P < 0.003$) hot carcass weights (98.70 kg) than pigs from the CS harvest (95.39 kg) which had heavier ($P < 0.003$) hot carcass weights than pigs from the HS harvest (91.60 kg; Table 1). Pigs from the HS harvest had the greatest ($P < 0.003$) AUS fat depth (2.19 cm), but the lightest ($P < 0.003$) hot carcass weight, and second greatest ($P < 0.003$) AUS LM depth, resulting in a lower ($P < 0.003$) calculated lean percentage than pigs from the TMP or CS harvests. The differences between harvests for lean percentage did not give any seasonal harvest group a different value-based grid carcass adjustment from the packing plant's premiums and (or) discounts and, though statistically different, are probably of marginal biological significance.

Table 1. Carcass compositional endpoints by harvest group

	Harvest group			
Variable	Temperate	Cold stress	Heat stress	*P*-value
Hot carcass wt, kg	$98.70^c \pm 0.63$	$95.39^d \pm 0.60$	$91.60^e \pm 0.61$	< 0.001
Last rib fat depth, cm	$2.82^c \pm 0.45$	$2.57^d \pm 0.44$	$2.79^c \pm 0.43$	< 0.001
Last lumbar fat depth, cm	$1.94^d \pm 0.05$	$1.88^d \pm 0.04$	$2.13^c \pm 0.04$	< 0.001
Avg. AUS[a] fat depth, cm	$1.95^d \pm 0.04$	$1.74^e \pm 0.04$	$2.19^c \pm 0.04$	< 0.001
Avg. AUS[a] LM depth, cm	$6.99^c \pm 0.06$	$6.64^e \pm 0.06$	$6.82^d \pm 0.06$	< 0.001
Lean Percentage[b]	$55.12^c \pm 0.16$	$55.09^c \pm 0.15$	$54.22^d \pm 0.15$	< 0.001

[a] Animal Ultrasound Services (AUS), Carcass Value Technology System; recorded as average depth from the 9th to 11th rib.

[b] Lean percentage calculated using NPPC (2000) formula from fat and muscle depths obtained by AUS.

[c, d, e] Within a row, values lacking a common superscript letter differ ($P < 0.003$)

Effect of Ante-mortem Stressors on Digestive Tract Temperature

Seasonal Environment

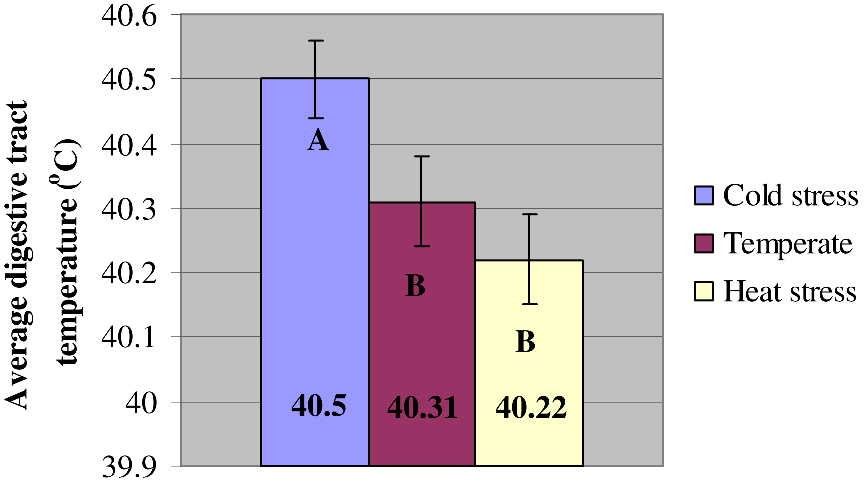
To effectively interpret the experiment, it is important to first gain an appreciation of how thermoregulation works in pigs. Physiological thermoregulation of pigs is primarily driven by changes in heat dissipation via peripheral blood flow (vasoconstriction or vasodilatation), evaporative cooling via panting, and, in cases of non-sensible hypothermia, heat generation via shivering (Curtis, 1985a). The peptic/anterior hypothalamus within the brain serves as the primary "*thermostat*" and utilizes norepinephrine, bradykinin, and nitric oxide as effectors (Charkoudian, 2003). Peripheral blood flow is predominantly driven by sympathetic vasoconstrictor nerves and sympathetic vasodilator nerves.

No known literature describes in detail the processes of physiological thermoregulation in pigs; however, extensive research has been conducted in humans. In human heat stress (hyperthermia), the sympathetic vasodilator system can increase skin blood flow to 6 to 8 L/min (or 60% of cardiac output) as the skin or internal temperature rises (Johnson and Proppe, 1996; as cited by Charkoudian, 2003). This increase of blood flow to the periphery increases convective heat transfer from the core to the periphery (Charkoudian, 2003). In human cold stress (hypothermia), the sympathetic vasoconstrictor system decreases blood flow by shifting blood flow from the periphery to deep veins (Rowell, 1983). This results in a decrease in heat dissipation from the skin and less convective heat transfer from the core to the periphery (Charkoudian, 2003).

Prior to handling (0245 to 0359 h), CS pigs had higher digestive tract temperatures (P < 0.04) than pigs from the other two harvests (Figure 1). During this time, the average ambient temperature during the CS collection was – 6℃ compared with temperatures of 8℃ during TMP collection and 22℃ for HS collection. The higher digestive tract temperature of the CS pigs indicates that these pigs had reached their *lower critical temperature* (as compared to the TMP and HS pigs) which we believe resulted in peripheral vasoconstriction and core thermal conservation. The lower critical ambient temperature of market weight pigs relative to cold stress has been estimated to be from 2 to 25℃ (Close, 1981; Curtis, 1985a). As ambient temperature approaches the pig's threshold for cold stress, peripheral vasoconstriction will increase the pig's tissue insulation. This will help to inhibit skin temperature decrease by narrowing the skin-to-environment temperature gradient and decreasing heat loss (Curtis, 1985). Additionally, the findings that CS pigs had higher digestive tract temperatures than TMP pigs suggests that the actual lower critical temperature of resting market hogs of this genotype is actually less than 8℃.

Conversely, the HS pigs had not reached their upper critical ambient temperature, which is estimated to be from 20 to 34℃ (Ingram, 1964; Stephens and Fox, 1969; Curtis, 1985b). When ambient temperature approaches the pig's upper threshold for heat stress and core body temperature begins to rise, peripheral vasodilatation will reduce the pig's tissue insulation, allowing skin temperature to rise. This widens the skin-to-environment temperature gradient and ultimately increases heat loss (Curtis, 1985b; Webb, 1995). The finding that HS and TMP pigs were not different relative to digestive tract temperature suggests that the actual upper critical temperature of resting market hogs of this genotype is greater than 22℃.

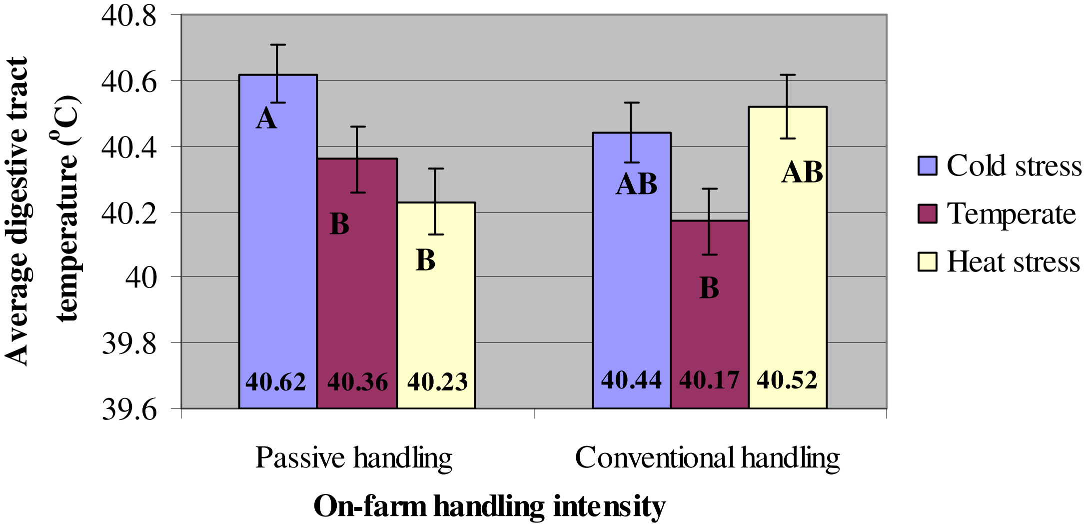
Figure 1. Main effect of seasonal environment on average digestive tract temperature of market hogs (*P* = 0.008) prior to loadout (0245 to 0359 h). Means lacking a common letter differ (*P* < 0.04).



On-Farm Handling Intensity

On-farm handling intensity did not have a direct effect *(P* = 0.733) on digestive tract temperature of pigs during loadout (0400 to 0530 h). However, during handling (0400 to 0530 h), PAS handled pigs from the CS harvest had higher digestive tract temperatures ($P < 0.05$) than all pigs from the TMP harvest and PAS handled pigs from the HS harvest (Figure 2). The PAS handled CS pigs were moved at a slow enough pace that body metabolism was not accelerated to a level that decreased digestive tract temperature. Thus, it can be assumed that pigs continued to have peripheral vasoconstriction. However, the added activity of CONV handled CS pigs accelerated their body metabolism, alleviating the need for vasoconstriction in maintenance of core body temperature.

Figure 2. Interactive effect of seasonal environment and on-farm handling intensity on average digestive tract temperature of market hogs (*P* = 0.018) during loadout (0400 to 0530 h). Means lacking a common letter differ (*P* < 0.05).

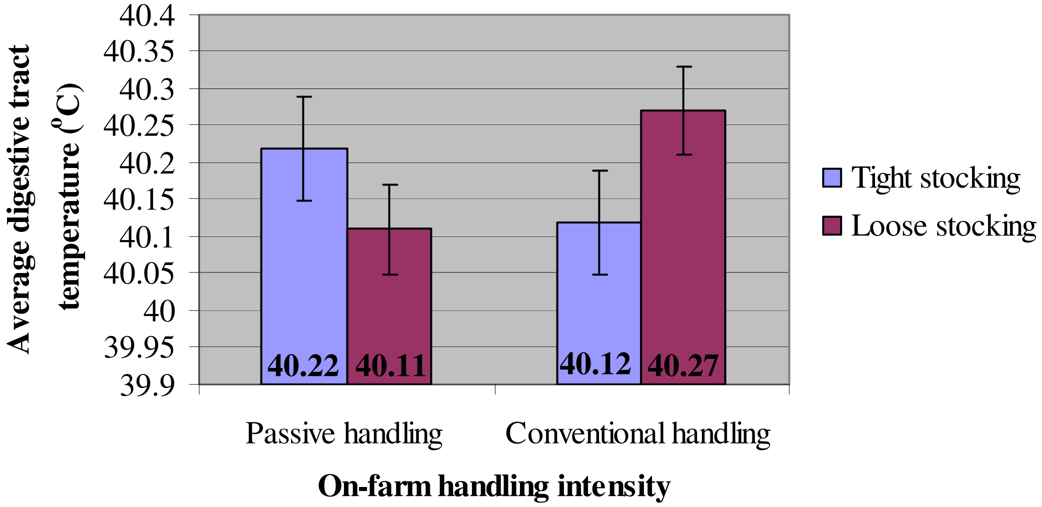


Prior to handling (0245 to 0359 h), pigs from the HS harvest had lower ($P < 0.05$) digestive tract temperatures than pigs from the CS harvest (Figure 1). However, during handling, pigs from the HS harvest that were handled CONV displayed no difference ($P > 0.40$) in digestive tract temperature compared to pigs from the CS harvest that were handled PAS (Figure 2). This suggests that the added activity during CONV handling accelerated the body metabolism of the HS pigs, raising their digestive tract temperature.

Stocking Density

Seasonal environment, on-farm handling intensity, and transport stocking density did not have a direct affect *(P* > 0.418) on digestive tract temperature of pigs during transport (0531 to 0800 h). However, during transport (0530 to 0800 h), pigs that were handled CONV and allotted to a LSD tended ($P = 0.088$) to have higher digestive tract temperatures than pigs that were PAS handled and transported at a LSD (Figure 3). This suggests that the added activity of CONV handled pigs accelerated their body metabolism compared to PAS handled pigs, potentially leading to higher digestive tract temperatures.

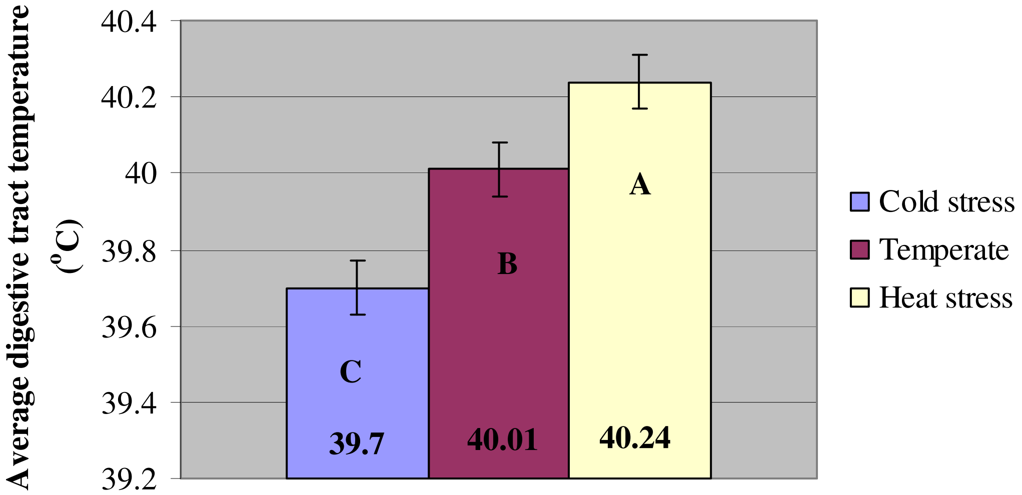
Figure 3. Interactive effect of on-farm handling intensity and transport stocking density on average digestive tract temperature of market hogs (*P* = 0.056) during transport (0531 to 0800 h).



Time in Lairage

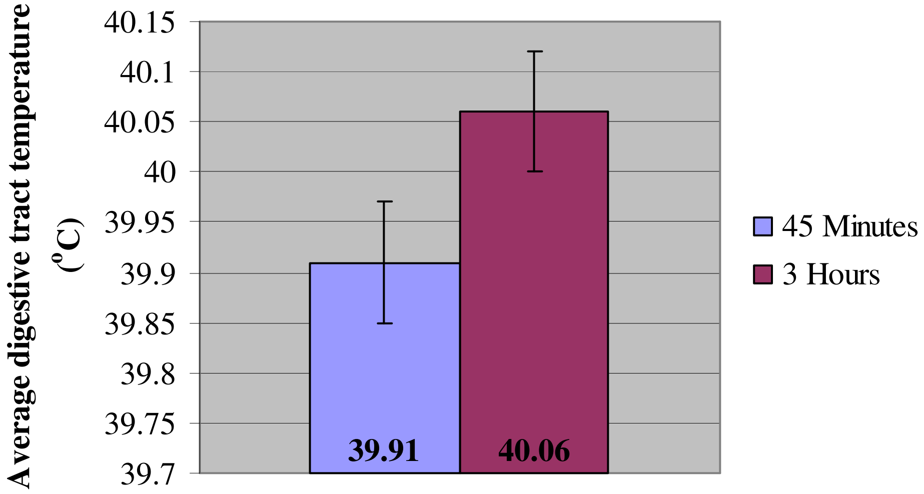
On-farm handling intensity and transport stocking density did not affect *(P* > 0.589) digestive tract temperature of pigs during lairage (0801 to exsanguination). However, during lairage (0800 to exsanguination), pigs from the HS harvest had higher (P = 0.001) digestive tract temperatures than pigs from the TMP harvest, which had higher (P < 0.03) digestive tract temperatures than pigs from the CS harvest (Figure 4). This suggests that the activity associated with the re-establishment of hierarchical dominance accelerated the metabolism of the HS pigs (Warriss et al., 1998; Brown et al., 1999). This could potentially raise their digestive tract temperature and initiate peripheral vasodilatation. Likewise, re-establishment of dominance of the CS pigs accelerated their metabolism, decreasing digestive tract temperature which eliminated the physiological need for peripheral vasoconstriction.

Figure 4. Main effect of seasonal environment on average digestive tract temperature of market hogs ($P < 0.001$) during lairage (0800 to exsanguination). Means lacking a common letter differ ($P < 0.03$).



Pigs subjected to the longer 3 h lairage tended (P = 0.06) to have higher digestive tract temperatures than pigs subjected to the shorter 45 min lairage (Figure 5). This can be explained by the hypothesis stated earlier; pigs remaining in lairage for 3 h had the opportunity to re-establish dominance within the pen, potentially accelerating their metabolism and raising their digestive tract temperature (Warriss et al., 1998; Brown et al., 1999).

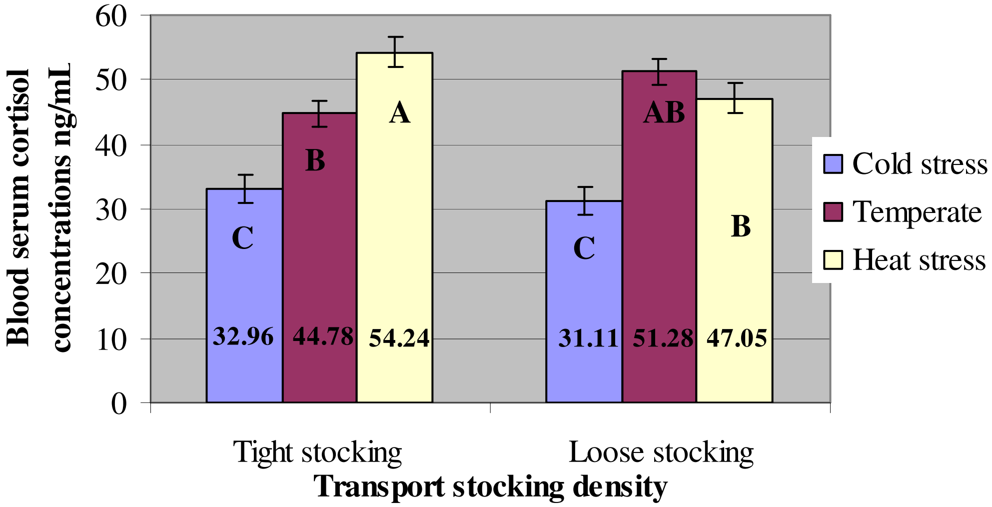
Figure 5. Main effect of length of lairage on average digestive tract temperature of market hogs ($P = 0.06$).



Effect of Ante-mortem Stressors on Blood Serum Cortisol Levels

Pigs from the CS harvest had lower ($P < 0.021$) blood serum cortisol levels than pigs from the other two harvests, regardless of stocking density (Figure 6). The relationship of low ambient temperatures with increased blood serum cortisol levels of nursery age pigs (Frank et al., 2003) and adult humans (Wilkerson et al., 1974) is well established; however, little research exists for the effects of low ambient temperatures on the stress response of market-weight hogs. The average ambient temperature during the CS harvest was -6°C, lower than all estimates for lower critical ambient temperature for market weight pigs which range from 2 to 25°C (Ingram, 1974; Close, 1981; Curtis, 1985a). This suggests pigs from the CS harvest should have been more stressed (higher blood serum cortisol levels) than pigs from the TMP harvest when the average ambient temperature was 8°C. However, the opposite was displayed in this study, this could be attributed to desensitizing of the CS pigs to low ambient temperatures, possibly limiting increases in blood serum cortisol levels (Becker et al., 1985).

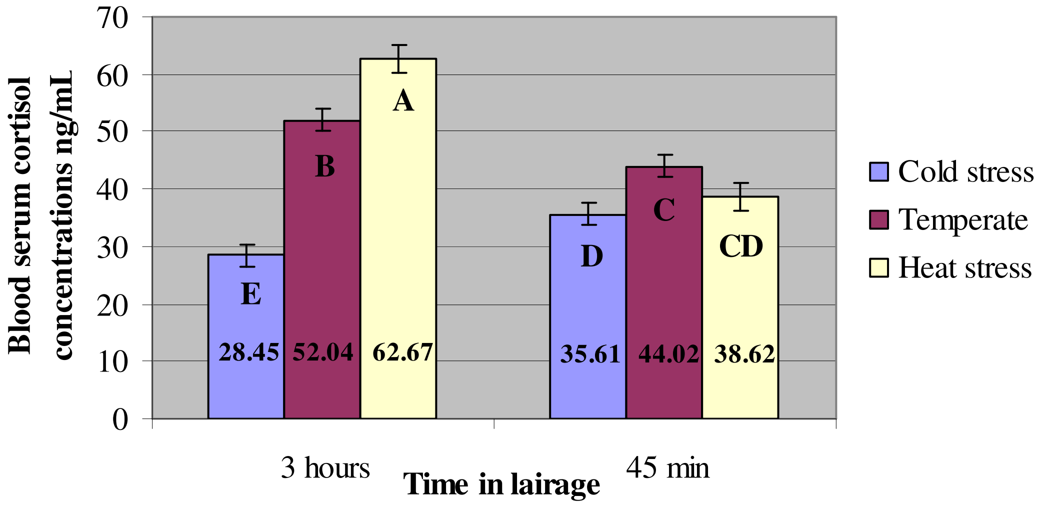
Figure 6. Interactive effect of seasonal environment and transport stocking density on blood serum cortisol levels. (*P* = 0.005). Bars lacking a common letter differ (*P* < 0.021).



Pigs from the HS harvest given 3 h of lairage had higher (*P* < 0.011) blood serum cortisol levels than pigs from the TMP harvest given the same time in lairage (Figure 7). Furthermore, pigs from the HS and TMP harvests given 3 h of lairage had higher (*P* < 0.011) blood serum cortisol levels than pigs from the same harvests given 45 min of lairage (Figure 7). These findings contradict the reports of numerous authors (Warriss et al., 1992; Warriss et al., 1998; Brown et al., 1999) who found pigs given ≥ 3 h of lairage had lower blood serum cortisol levels than pigs given ≤ 1 h of lairage. Again, it is important to note that the variation in ambient temperature was not accounted for within the statistical model of these previous research initiatives. Collectively, these results are consistent with findings for digestive tract temperature during time in lairage relative to seasonal environment and lairage length, suggesting 3 h of lairage exacerbates stress when pigs are exposed to high ambient temperatures.

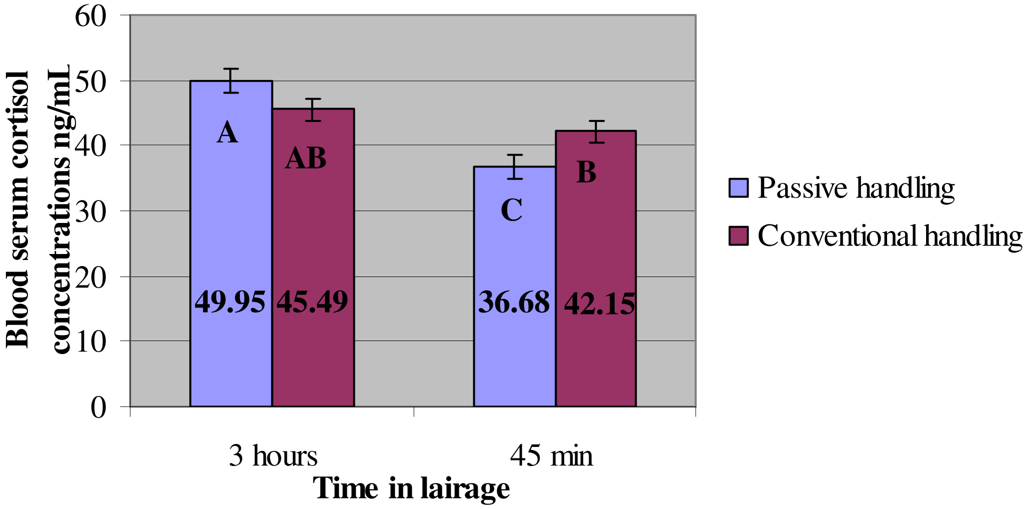
Pigs from the CS harvest given 3 h of lairage had lower (*P* < 0.011) blood serum cortisol levels than pigs from all other seasonal environment × time in lairage combinations (Figure 7). A longer time in lairage would allow pigs more time to recover from the stresses of transport, potentially lowering blood cortisol levels, particularly if a low ambient temperature does not induce a stress response in market-weight pigs

Figure 7. Interactive effect of seasonal environment and time in lairage on blood serum cortisol levels. (*P* < 0.001). Bars lacking a common letter differ (*P* < 0.011).



Pigs given 3 h of lairage did not differ *(P* > 0.10) for blood serum cortisol levels across on-farm handling intensity; however, PAS handled pigs given 3 h of lairage had higher (*P* < 0.03) blood serum cortisol levels than CONV handled pigs 45 min of lairage (Figure 8). Pigs given 3 h of lairage had the opportunity to become stressed via the re-establishment of dominance within the lairage pen, potentially raising blood serum cortisol levels (Brown et al., 1998). Pigs handled CONV then given 45 min of lairage had higher (*P* < 0.03) blood serum cortisol levels than pigs handled PAS with a corresponding 45 min lairage (Figure 8) This suggests that pigs given PAS on-farm handling reduces stress and lowers blood serum cortisol levels, compared with CONV handling (Grandin, 1997).

Figure 8. Interactive effect of on-farm handling intensity and time in lairage on blood serum cortisol levels. ($P = 0.003$). Bars lacking a common letter differ ($P < 0.03$).



Summary and Implications

Subjecting pigs to conventional on-farm handling during loadout and (or) a tight stocking density increases blood serum cortisol levels and digestive tract temperatures. However, the most substantial affects were seen when pigs were given 3 h of lairage during the heat stress harvest. Pigs exposed to heat stress (22 to 35°C) had higher digestive tract temperatures during lairage and higher blood serum cortisol levels than pigs from the temperate (6 to 13°C) and cold stress (-9 to 0°C) harvests. These problems were exacerbated when pigs were given the longer 3 h lairage. During periods of heat stress (≥ 22°C), pigs should be kept in lairage less than 3 h prior to harvest to minimize increases in digestive tract temperature and ultimately improve animal welfare.

Lay Interpretation: This research was conducted to evaluate the effect of three seasons of the year: fall, summer, and winter, how pigs were handled on-farm: aggressive yet conventional and very easy, two transport stocking densities: tight and loose, and two resting periods at the plant prior to harvest: 45 min and 3 h, on the digestive tract temperature and cortisol in the blood of market hogs. The day before harvest, a computer-activated temperature logging device (Ibutton), was placed down the throat of the market hogs. Half of all hogs were handled very easily on the farm and the other half were handled more aggressively. As pigs were loaded, approximately half of the pigs were loaded at a tight stocking density, (all pigs could not lie down at the same time, 0.4 m^2/pig) and the other portion were loaded at a looser density (all pigs could lie down at the same time, 0.5 m^2/pig). When arriving to the packinghouse, half of the test animals were harvested after a 45 min rest and the other half after a 3 h rest. Blood was collected at bleeding for testing cortisol. Ibuttons were collected from within the gut after harvest.

Prior to handling, pigs from the winter harvest had higher digestive tract temperatures than pigs from the other two harvests. However, during handling, pigs from the summer harvest that were handled more aggressively did not have different digestive tract temperatures than pigs from the winter harvest that were handled very easily. This suggests that more aggressive handling accelerated the body metabolism of the summer pigs, raising their digestive tract temperature. During pre-harvest resting, pigs from the summer harvest had higher digestive tract temperatures than pigs from the fall harvest, which had higher temperatures than pigs from the winter harvest. This suggested that the hot environment combined with fighting and mixing at the packing plant accelerated the metabolism of the summer pigs. Most pigs subjected to the longer pre-harvest rest period had higher digestive tract temperatures than pigs subjected to the shorter resting period. The results for season and rest period prior to harvest were similar to the digestive tract temperatures. Cortisol concentrations were higher from pigs given the longer resting period. Additionally, pigs from the summer harvest had a higher coritsol concentration than pigs from the other two harvests.

Overall, pigs harvested in the winter began the day trying to maintain heat and body temperature, so they had the highest digestive tract temperatures prior to handling and trucking. By the time they were harvested, their activity raised their temperature, and they no longer needed to conserve heat, so their digestive tract temperature went down. Pigs harvested in the summer began the day trying to get rid of body heat (cool down), so they had the lowest digestive tract temperatures prior to handling and trucking. By the time they were harvested, their activity combined with heat stress raised their body temperature to a point that they were not able to get rid of all the added body heat, so they had the highest digestive tract temperatures during the resting period prior to harvest. Additionally, the higher cortisol concentration from the summer group suggests their level of welfare may be lower than pigs from the other two harvests. Additionally, digestive tract temperatures and blood cortisol concentrations were higher from the pigs given the longer pre-harvest resting period, especially during the summer harvest. Collectively, it appears that during times of summer heat stress, pigs should not be allowed to rest as long to prevent further fighting and restlessness at the plant. The other solution may be to rest the pigs longer than 3 h prior to harvest to allow them to more fully recuperate from previous stresses. However, that conclusion cannot be made from this experiment since we did not evaluate body temperature of the pigs at the packing plant longer than 3 hours.

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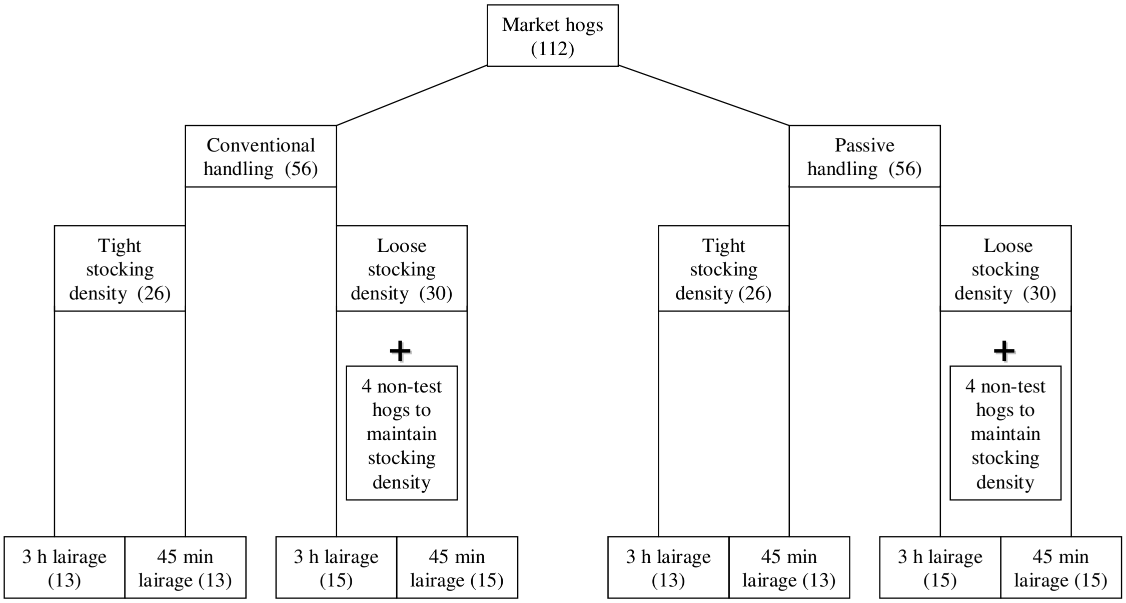
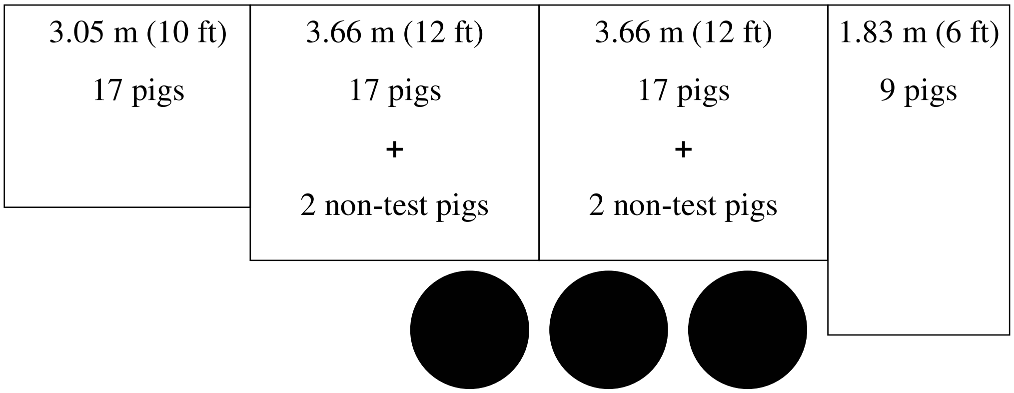
Appendix A



This replication will occur at three different environmental situations, giving the total project (n=336).

Appendix B



Trailers were 2.13 m (7 ft) wide. Both trucks had identical trailer dimensions.