

ABSTRACT

YODER, CHAD LEWIS. Estimates of Breed Differences and Genetic Parameters of Pig Temperament Scores during a Performance Test and its Relationship with Performance Traits. (Under the direction of Dr. M. Todd See).

The objectives of this study were to estimate breed differences for temperament scores during a performance test, and estimate genetic parameters associated with temperament and performance traits. Chester White (CW), Duroc (D), Landrace (L), and Yorkshire (Y) boars and gilts (n=4,774) were used to estimate breed differences in temperament and (co)variance parameters. Adjusted backfat (BF), adjusted loin depth (LD), days to 113.4 kilograms (DAYS), estimated percent fat-free lean (LEAN), and three temperament scores: load score (LS), scale score (SS), and vocal score (VS) were recorded. All scores ranged from 1 (calm) to 5 (highly excited). Load score was recorded while loading into the scale; SS and VS were recorded while in the scale as ultrasound measurements were taken.

Temperament scores were evaluated as categorical traits with generalized linear models including fixed effects of breed, sex, contemporary group (barn-farm-test date), and off-test weight as a covariate. Order in which pigs were loaded into the scale was included as a fixed effect in the model for LS. After initial analysis it was determined VS was best described as a binary trait, vocal and non-vocal, and was analyzed accordingly. Statistical models for BF, LD, DAY, and LEAN included fixed effects of breed, sex, and LS, SS, or VS. Growth rate was adjusted to 113.4 kilograms, while BF and LD were adjusted to 113.4

kg through regression on mean off-test weight of respective breed. Breed differences for LS, SS, and VS were estimated as odds ratios.

The odds of increased LS were greater for L (1.62, 1.30; $P < 0.01$) than D and Y respectively. Landrace had a greater ($P < 0.01$) probability of a higher SS and VS compared to CW (1.77, 2.37), D (3.31, 3.94) and Y (2.51, 2.46). Yorkshire had greater odds of increased LS (1.25), SS (1.32), and VS (1.60) than D. Chester White had a greater probability of increased LS and SS than D (1.58, 1.87) and Y (1.26, 1.42). Chester White were 1.66 ($P < 0.01$) times more likely to have a higher VS than D.

Genetic models for LS, SS, VS, and performance traits were the same as those used to estimate breed differences. However, breed was excluded as a fixed effect and a separate analysis was conducted for each breed. Temperament scores were not included in models for performance traits. Variance components were estimated using Gibbs Sampling through THRGIBBS1F90 software with 150,000 cycles, a 20,000 cycle burn in period, and every 20th sample was stored. Estimates of parameters of interest were obtained as statistics of their respective posterior distributions.

Direct heritability estimates were (CW, D, L, Y): LS (0.05, 0.06, 0.06, 0.05), SS (0.22, 0.09, 0.09, 0.10), and VS (0.27, 0.24, 0.37, 0.21). Estimated heritability for LS was low regardless of breed. Heritability estimates for SS, were low with the exception of CW. Heritability estimates for VS were moderate. Direct genetic correlations between SS and VS obtained in a bivariate model were positive and moderate (0.30 to 0.75) indicating that pigs that are more active in the scale are also more vocal. Genetic correlations between temperament traits varied among breeds, but were generally moderate and positive. The

genetic correlations between LS, SS, and VS with BF, LD, DAYS, and LEAN ranged from -0.78 to 0.56, and varied among breeds. Based on these results it was concluded that selection for temperament scores collected during a performance test provide potential to alter pig behavior. However, progress in performance traits may be affected if selection for temperament is practiced, while current selection criteria may result in changes in temperament.

Estimates of Breed Differences and Genetic Parameters of Pig Temperament Scores during a
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by
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BIOGRAPHY

Chad L. Yoder was born and raised in Lone Tree, IA, and grew up cheering for the Iowa Hawkeyes. Chad spent most of his time playing sports, basketball, golf and baseball, and working on the family farrow-to-finish hog and row crop operation. Chad's interest in the swine industry grew as he began raising his own pigs when he was 10 years old. His interest grew as he began to increase the size of his herd until he owned interest in 20 commercial sows.

Chad began his undergraduate program in Animal Science at Iowa State in the fall of 2004. Through classes and work with Dr. Tom Baas, Chad became interested in swine genetics. As a result Chad began a small purebred Duroc herd with his father Kent.

After finishing his Bachelor of Science degree in May of 2008, Chad worked for Genetiporc before beginning his Master of Science program at North Carolina State University. After graduation Chad plans to return to Iowa State to pursue a Doctorate of Philosophy under the direction of Dr. Tom Baas.

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CHAPTER 1

LITERATURE REVIEW

TEMPERAMENT, BEHAVIOR AND PERFORMANCE IN SWINE

INTRODUCTION

Breeding programs in the swine industry are designed for the selection of animals that will produce multiple large litters of pigs that grow quickly and efficiently, and produce high quality lean meat, resulting in increased profits for the producer. Pigs that perform best in the environment in which they are raised are selected. Pig temperament, or behavior, is often over-looked when selecting the best performing pigs. It has been speculated that intense selection for growth and leanness in cattle resulted in increased problems with temperament, including increased aggressiveness during handling and more excited response to restraint in a chute (Grandin et al., 1998).

Over the past few decades the physical environment in which pigs are raised has changed dramatically. Integration of the pork industry has led to fewer, larger producers. The move to efficiently mass produce pork resulted in more standardized production environments across the industry. Large scale sow farms and grow to finish operations have implemented standardized confinement environments to utilize limited amounts of space for the most efficient production of pork. This has resulted in fewer producers managing more pigs. Pig to producer contact was reduced, therefore decreasing the opportunity for pigs to become familiar with humans, and creating the potential for pigs to relate handling with stress (Le Neindre et al., 1998).

Modern production systems provide a more consistent environment than in the past, and meet the physical and biological needs of pigs. However, there is increasing public

concern for the animal's welfare in confinement. Changes are starting to occur in pig housing in an attempt to better account for the animal's welfare, especially in sow housing.

With changes come new problems that need to be resolved. Breeding programs will need to consider introducing traits that will impact animal well-being, while maintaining efficiency of production. Animal welfare is considered to be a socially important trait that is considered to be non-economical (Kanis et al. 2005). This includes behavior and temperament which can be divided into many other categories. All have societal values, while some also have economic values. Determining which traits will be useful and how to measure them will be a tall task for swine breeders.

Temperament is defined as individual behavioral differences which are repeatable over time and across situations (Reale et al., 2007; D'Eath et al., 2002a; Sih et al., 2004). Temperament occurs across all types of production environments and includes maternal behavior (Jarvis et al., 2005; Rydhmer, 2000), aggressiveness (D'Eath et al., 2002a), social behaviors (McGlone 1991, Lovendahl et al., 2005), feeding behaviors (Georgsson et al., 2002), daily activities (Sekiguchi et al., 2004), reactions to humans and handling (Phocas et al., 2006; Hemsworth et al., 1990), responses to new objects or situations (van Erp-van der Kooij et al., 2002), and coping behaviors (Cassady, 2007). These traits are measured by response to a situation, and can be compared to other pigs in the same environment, and also to behavior of wild pigs (Graves, 1984).

Traits described are indirect measures of temperament and unfavorable behaviors can have adverse effects on animal welfare, including decreased immune function, stress, survival, or injuries (Turner et al., 2006). Increased reactivity to a stressful situation has been

shown to reduce productivity (Forkman et al., 2007). Temperament had an effect on performance including growth, carcass traits, and meat quality (Warriss et al., 1998; D'Eath, 2002a; Cassady, 2007).

With increasing pressure to raise pigs with certain welfare standards, measures of temperament and behavior may have increasing importance in selection and breeding decisions. Pigs that excel in performance will be selected, but temperament of those pigs should be considered when selection decisions are made. Potential inclusion of temperament measures into a breeding program, and understanding effects that it will have on performance is important. The swine industry has the opportunity to produce pigs that meet societal values and efficiently produce quality pork.

TEMPERAMENT

Temperament can be defined many ways, can be measured at different times during production, and has many methods of measurement. Temperament can be defined in terms of level of fear that an animal shows toward humans and novel objects (Rdyhmer, 2000). A measure of this fear could be a reaction to a human interaction, a new situation, or any object that is new to an animal.

Temperament can also be classified by traits defining individual consistency in behavior over time and across situations (Reale et al., 2007). These traits are ones that can be measured individually and can be repeated over time. Examples of these traits would be coping behavior such as a backtest or resident intruder test. Aggressiveness, sociality, feeding, sleeping, competition, and exploration could also be included. Maternal behaviors

during farrowing and lactation, such as a sow's posture, sow-piglet communication, eating, and drinking habits are other measures of temperament.

The characteristic phenomena of an individual's nature, including its susceptibility to stimulation, its customary strength and speed of response, quality of its prevailing mood, and all peculiarities of fluctuation and intensity of mood define temperament of mammals (Reale et al., 2007). This covers any type of reaction a pig may have to a situation or any type of behavior that is considered abnormal for a pig. This can be compared to Wild Pig behavior and could include traits such as tail biting. Behavioral syndromes are correlated behaviors reflecting individual consistency in behavior across multiple situations (Sih et al., 2004) and can be identified across situations. This may include reactions to several stressors at one time including separation weaning, moving, mixing, and vaccinations. Reactions to events at a young age can be used as predictors of future behavior (D'Eath et al., 2004).

TEMPERAMENT OF THE WILD PIG

Although pigs were domesticated five to ten thousand years ago, temperament of the domesticated pig still resembles that of its ancestors. Understanding Wild Pig temperament may lead to a better understanding of different temperaments seen in modern swine production.

In the wild, pigs utilize their noses to search for food, and many management problems with domestic swine stem from lack of occupancy of the pig's nose (Hartsock 1982). Tail-biting may be a result of the lack of opportunity for the pig to use its nose. Pigs that were hand raised by humans tend to spend more time around humans and are more receptive to their presence (Lewis 1966).

Maternal behavior is very similar to that of pigs in current commercial production systems. A sow's vulva swells around three days prior to farrowing, and she begins nesting behavior, which is altered by modern farrowing crates. Throughout the process of farrowing, a sow's temperament becomes increasingly protective and unpredictable.

Post-farrowing piglet behavior, such as teat-seeking behavior, occurs in both wild and domestic pigs. Some sows also show aggressive behavior toward their pigs and occasionally savage them. Feeding behavior of the wild pig changes as the seasons weather change. The colder the weather is the more pigs eat (Graves 1984). Domestic pigs show similar behavior, however, with the increase of confinement operations, environment is more controlled, lessening this effect.

Although the environments that wild pigs and domestic pigs are raised in are very different, pigs still exhibit similar temperaments. Domestic pigs may be restricted, but while they can't roam or wallow, they still express those behaviors in their environments. Understanding what behaviors pigs tend to exhibit helps us to understand behaviors that are abnormal for the pig and how it may affect performance.

MATERNAL BEHAVIOR

The sow's behavior provides an important role in the success of a litter. The feeding behavior of a sow can determine how much energy she has, and the quantity and quality of milk that she can produce for her pigs. Savaging of young piglets can be a problem in a farrowing operation, and can cause significant loss of pigs during lactation. Quantifying a sow's aggression toward her pigs in the first few days after farrowing, when pigs are the most fragile, is important for management of the sow and litter.

In a study from Knap and Merks (1987), three different commercial sow herds in the Netherlands were used to determine frequency and effect of sow aggression toward their piglets. A sow's aggression was defined as either non-aggressive or vigorously aggressive. Incidence of sow aggression was not scored differently if the pig was able to escape or if it ended in injury or death. Nearly eight percent of primiparous sows were vigorously aggressive, which resulted in two fewer pigs weaned per litter.

Van der Steen et al. (1988) partitioned sow aggression into four categories of subjective behavior; a) normal behavior; b) sow was restless but not aggressive; c) sow was aggressive against her piglets but caused them no injury; and d) sow caused injury or death to her piglets. Seven to twelve percent of sows were considered to be aggressive, and sows that weighed less and were leaner after parturition were more predisposed to aggressive behavior.

While pigs can be injured or killed by aggressive sows, many pig injuries are caused by being crushed under the weight of a sow as she lies down. A sow must get up to eat and drink, and is required to lie down frequently to nurse her pigs. During movement the opportunity for pig injury or death greatly increases and the pattern of these movements have a large influence on pig mortality (Rydhmer, 2000). Sows that produce larger litters are also more likely to have an increase in crushing. In a study by Jarvis et al. (2005) a regression coefficient of 0.30 was recorded for occurrence of crushing with increasing litter size. Crushing was also found to be highly repeatable (0.52) for posture changes with high crushing risk such as lying down.

Tanaka et al. (2007) recorded three types of postural behavior; lying, sitting and standing, over a twenty-four hour period. When sows increased postural change five times in

a 24 hour period they were 1.025 times more likely to have an occurrence of greater than 2 dead piglets during lactation. As parity increased the time a sow spent standing increased significantly. Sows that went from a standing position to a lying position accounted for fifty-four percent of observed piglet crushing deaths.

Response of a sow to vocalization of her pigs can cause a sudden change in posture and behavior. Lovendahl et al. (2005) recorded a sow's beginning posture as lying on her side or belly prior to an observer picking up and handling a pig. After a pig was picked up, the sow's reaction was recorded as one of the following responses: a) lying; b) looking up but still lying; c) sitting; d) standing; e) attacking person; f) or vocalization.

Maternal behavior, whether it is aggressive tendency or postural changes, has significant effects on piglet survival. Sows that are more active in their postural changes are more likely to lie on their pigs and injure them. Utilizing sows that are less aggressive and less active should improve piglet well-being.

FEEDING BEHAVIOR

All aspects of an animal's productivity depend on the animal's behavior. To mate is to express reproductive behavior, to nurse pigs is to express maternal behavior, and to gain weight is an expression of feeding behavior. Feeding behavior is important in all aspects of swine production, sows need energy to produce milk for their pigs, grow-finish pigs need energy to grow, and lack of energy may cause problems during transportation.

Finding a valuable measure of feeding behavior is difficult because feeding is not a constant behavior, and occurs multiple times during the day. A human observer can count number of visits to a feeder, but can't measure feed intake, triggering a move to mechanical

devices for measurement (McGlone, 1991). Using computerized feeders enables number of visits to the feeder per day, daily feed intake, amount of feed consumed per visit, daily eating time, length of time per visit, daily non-feeding time in the feeder, eating rate, and number of non-feeding visits to be recorded or calculated (Hyun et al., 1997; Rauw et al., 2006). These measures allow for the calculation of average daily gain and feed conversion efficiency.

Georgsson et al. (2002) measured feeding behavior traits to compare competition effects of pigs in pens with either one or two feeders available to the pigs. Pigs that had less competition visited the feeder more often, ate less per visit, and had less feed intake per day. Pigs with less competition had greater daily weight gain, and grew more efficiently. Competition for time at the feeder had a significant effect on the pig's feeding habits which resulted in decreased performance.

Temperature also has an effect on pig feeding behavior. A range of low temperatures (12, 14, 16, 19, 22 degrees Celsius) were applied to pigs to determine the effect on feeding behavior. As temperature increased time spent at the feeder decreased, feed intake decreased, but rate of intake increased. Another range of high temperatures (19, 22, 25, 27 degrees Celsius) were applied and as temperature increased, pigs made fewer trips to the feeder, and had less feed intake (Quiniou et al., 2000).

Pigs that ate faster tended to grow faster and fatter, compared to pigs that consumed feed more slowly. Pigs that ate quicker tended to have a higher feed intake. However, as the frequency of trips to the feeder increased, feeding length, rate, intake, growth rate and back fat deposition all decreased (Rauw et al., 2006).

Similar feeding measures have been recorded in cattle. Daily feeding duration, feeding head down time, and feeding frequency were measured, along with a temperament measure known as flight speed. Phenotypic correlations between daily feeding duration, feeding head down time, feeding frequency and flight speed were 0.42, -0.56, and -0.11 respectively, indicating feeding behavior may affect or be affected by other behaviors. Feeding duration had correlations of 0.25 with head down and -0.40 with feeding frequency. Feeding frequency had a correlation of 0.47 with head down time. Feeding duration was positively and favorably correlated with carcass weight, carcass grade, carcass marbling, and carcass loin muscle area. Cattle that fed more often had lower carcass weight, graded more poorly, and had a lower yield grade (Nkrumah et al., 2007).

Feeding behavior does affect performance in livestock. Utilizing information on feeding behavior may provide assistance to manage pigs that may suffer in competitive environments.

SOCIAL BEHAVIOR

Social behavior can be defined as the interaction between pigs. Wild pigs begin social behavior at a young age when they form a social dominance relationship with littermates during nursing. Pigs also form small gregarious groups, yet tend to become solitary around parturition and during feeding. During feeding and mating seasons pigs will fight when their space is invaded (Graves, 1984).

Domestic pigs also form a hierarchy of dominance during lactation. Hartsock et al. (1977) observed piglets during early lactation and found pigs that were heavier at birth tend to lead in nursing order. Fighting was observed during the first twenty-three hours post-

partum. Location of the teat at which the fight occurred, and identification of the winning pig were recorded. Winning the fight was defined as maintaining possession of the teat. Performance data were recorded on pigs throughout the growth phase to slaughter. Pigs that were heavier at birth won more fights and maintained the best teats (anterior teats) for nursing. Winning pigs had increased pre-wean growth rate (phenotypic correlation of 0.38) and lower mortality. Post weaning gain was highest in pigs that won fights. In another study by Gill et al. (1955), results were reported between piglet nursing order and pre-wean growth rate, and pigs that suckled anterior teats consistently grew faster. Piglets that exhibited aggressive responses within litters during lactation were more aggressive in later temperament measurements (D'Eath et al., 2004).

Sows that are housed in group pens are mixed after weaning, and may differ in parity and weight. In a study of sow aggression five to ten sows were led into a thirty square meter arena. For thirty minutes an observer recorded all counts of aggression. The sow initiating the fight and the sow that received aggression were recorded. Aggression was recorded as mild (a single blow or bite), or severe (multiple blows or bites). Aggression was found to be favorably correlated with maternal behavior (Lovendahl et al., 2005). In another study aggressive pigs were found to be first to feed and exhibit dominance over other sows in the pen. Pigs that were receivers of aggression spent more time in the corner and were timid around the feeder, resulting in lowered intake and slower growth (Erhard et al., 1997).

After weaning, pigs move to a nursery or finisher at which time they are comingled with pigs of similar size and age. When pigs are mixed and housed in group pens tail-biting may occur. Tail-biting may result from the lack of occupancy for a pig's snout. Sows have

also been found to show cannibalistic tendencies by eating their piglets (Graves, 1984). Tail-biting has been found to cause economic losses at market, and also is an animal well-being concern. Walker et al. (2006) scored the severity of tail-biting on a scale of zero to four. A score of zero meant no tail-biting and a score of four meant partial or complete loss of the tail. Pigs that grew faster and were heavier were more likely to be targets of tail-biting. Tail scores of three and four were associated with carcass condemnation.

In a study by Breuer et al. (2005) tail-biters were identified over a twelve month period. Breed and sex of the pigs doing the biting were identified. Tail-biting was unfavorably correlated with lean growth ($r = 0.27$) and backfat ($r = -0.28$) thickness. Kjaer et al. (1997) found similar cannibalistic actions in laying hens. Birds were moved into a pen and an adhesive strip was placed on their back for pecking identification. Birds were observed at six, thirty-eight, and sixty-nine weeks of age after being mixed at six weeks. Birds that were pecked were more likely to be weakened and continually pecked until pecked to death. The birds that were pecked the most also spent less time eating and were more timid. The resident intruder test is a measure of pig interaction. However, it is widely accepted as coping-behavior and will be discussed in a later section.

Social behavior is of interest to swine producers and the public. Actions of social behavior can result in injury or death of the pig. Quantification of social behavior will be important as the swine industry moves toward group sow housing, and keeps a watchful eye on pig well-being.

COPING BEHAVIOR

Coping behavior is the individual response to a stressor in order to reduce stress (Levine, 1989). Several types of tests have been recognized as reasonable measurements of coping behavior. Backtest, resident intruder test, and reactions to human presence are tests that have been used to measure coping behavior.

A backtest allows each pig to be tested as an individual and can be repeated. Each piglet is laid on its back, in the supine position, for sixty seconds. During the test a handler placed their hand over the front half of the pig, to prevent the pig from escaping, and records the number of escape attempts. Pigs were exposed to the backtest twice before weaning and number of escapes were added together, total time struggling was also recorded (Cassady, 2007; van Erp-van der Kooij et al., 2003). In early studies pigs that tried to escape twice were classified as resistant pigs, and non-resistant if less than two escape attempts. Piglets that averaged exactly two struggles, or were resistant one time and non-resistant another, were classified as doubtful (Hessing et al., 1994). Prewaning average daily gain increased as the number of struggles during a backtest increased. Pigs with a greater backtest score had a higher weaning weight. Backtest was also found to be moderately repeatable (0.18-0.49) (Cassady, 2007). Pigs that were considered more reactive had higher percent lean muscle and less backfat at slaughter. Highly reactive pigs were also heavier and had a higher growth rate than pigs that were less reactive to the backtest (van Erp-van der Kooij et al., 2003).

Pigs that were resistant expressed more frequent vocalizations, increased finishing average daily gain, higher carcass weights, and higher percent meat which resulted in higher payment to the producer when compared to non-resistant and doubtful pigs (Hessing et al.,

1994). Pigs that are more reactive to the stress inflicted on them during a backtest, perform better.

The resident-intruder test measures the aggressiveness of a pig toward another by determining the amount of time it takes for one pig to attack another. The intruder pig is introduced into a pen with a resident pig. Pigs are separated by a board and when the board is removed testing time begins. The test continues until one pig attacks the other or an allotted time is reached, usually three to five minutes. Erhard et al. (1997) recorded attack latency as time between introduction and attack. In another study pigs were tested twice, and scored by the number of times the pig attacked, 0, 1, or 2. Pigs that received a resident intruder score of 2 had an increased nursery gain of 44 grams/day, had 1.6 mm less backfat than pigs of score one, which resulted in greater lean gain (Cassady, 2007).

Pigs that weighed more at time of test were more likely to attack at seven weeks of age, but that effect dissipated as pigs grew older. When a male pig was attacked by a female pig, it was more likely to fight back than if the pig attacked was female. As the difference in weight between the resident, the heavier animal, and intruder, the lighter animal, increased the amount of time it took to initiate the attack increased (Erhard et al., 1997).

In another study of mixing, utilizing the resident-intruder test, the heavier pig in the fight initiated and won more fights. Pigs that had high average daily gains saw those gains decrease after they were involved in a fight, showing that mixing suppresses weight gain. Bullying was also more frequent amongst pigs that were considered aggressive. Pigs that initiated fights the first day were more likely to be aggressive on the second day of testing (D'Eath, 2002b).

As production systems become larger fewer people care for more pigs, decreasing the opportunity for pigs to acclimate themselves with human presence. The human test is a test of the reaction to the introduction of a human into the pig's environment. Pigs enter a pen and are allowed to acclimate for twenty minutes. A human then enters the pen and remains stationary for five minutes. Time taken for a pig to first interact with the human, total time spent interacting, and number of physical interactions are recorded. Pigs that interacted with the human more are considered to be more receptive and less stressed by human presence (Hemsworth et al., 1990; Giroux et al., 2000; Thodberg et al., 1999).

In a human test of twenty-five to thirty week old gilts ($n = 425$) more gilts that did not interact with the experimenter failed to be successfully mated. Gilts were separated by farm personnel into a breeding pen, in which they were naturally mated. Ninety-three percent of the gilts that interacted with humans were successfully mated, while only eighty-eight percent of gilts that did not interact were successfully mated. In addition, gilts that interacted with the human experimenter had a lower number of matings (2.31 v. 2.51) per litter farrowed (Hemsworth et al., 1990). In segregated early wean pigs, a study found pigs that were more receptive to human presence grew faster (Giroux et al., 2000).

Thodberg et al. (1999) performed a human presence study in adult gilts and found that exploration of the pen was highly and negatively correlated with time spent in contact with the human. Vocalization was positively correlated with exploration ($r = 0.46$), but lowly correlated with human interaction ($r = -0.18$). Although exploration is negatively correlated with time spent in contact with the human, it is highly and positively correlated with number of contacts with the human.

Coping behaviors are a way of measuring a pig's reaction to certain stressors. Pigs react differently to each other, humans, and being put into new situations. Some studies found an unfavorable relationship between backtest and performance. However most found an increase in reaction means that pigs are trying to relieve stress being caused by the situation. Pigs that reacted to stressors performed better including, faster growth, greater lean muscle, increased reproductive performance, and were leaner. An animal's ability to react to stress can prove important to its performance.

TEMPERAMENT SCORING

Quantifying behavior has been done for a variety of behaviors, but few studies have quantified a pig's temperament during a performance test. During a performance test performance traits are measured for selection, and it may be appropriate to score temperament for selection at this time. Several scores of activity while loading into a scale, activity while in the scale, and a vocalization while in the scale are traits easily measured during a performance test.

Load Score

There are no publications that have reported scores based on activity during loading of a pig into a scale, but loading of pigs onto trailers and how it affects a pig's stress level were reported. Three methods of loading pigs onto a commercial trailer were analyzed; using a hydraulic cart, an angled ramp, and a modular unit into which pigs were loaded, then moved by a fork lift. The modular unit allowed less stress through moving, and pigs loaded quicker and more easily. Pigs had lower heart rates and increased cortisol levels, which

indicated pigs responded better to stress when they were moved in a modular unit (Brown et al., 2005).

Grandin (1992) measured loading behavior in cattle, by quantifying the action of cattle entering a crush scale were classified as balkers or non-balkers. Non-balkers entered a crush scale voluntarily or with a light tap on the rump, while balkers received a hard slap on the rump or tail twisting. Cattle scored as balkers were more likely to exhibit a temperamental response when in the chute compared to non-balkers.

Scale Score

Measures of scale scores were first done in cattle (chute scores) and scale score used in pigs was adapted from that scoring system. Cattle were restrained in a manually operated squeeze chute and given a score rating their temperament as: 1) calm, stands still, no movement; 2) slightly restless; 3) restless, shaking the restraint device; 4) vigorously shaking the restraint device and attempting to escape; and 5) rearing, twisting body and struggling violently (Grandin, 1994; Grandin et al., 1998, Voisinet et al., 1997; Curley et al., 2006; Kadel et al., 2006; Grandin, 1992; Burrow et al., 2000).

In a study by Voisinet et al. (1997) feedlot cattle were given a scale score every 28 days while in the finishing phase of production. Two breed groups were analyzed and in each breed group average daily gain decreased as scale scores increased. Cattle that received a score of 1 had a 0.19 kg increase in average daily gain compared to cattle that received a score of 3. Calmer cattle grew faster than cattle that were easily excited. In a similar study by Burrow et al. (2000) cattle with higher chute scores weighed less at time of scoring, and had a trend of growing slower than cattle that received lower scale scores. Another study

that scored scale activity found that it was moderately to highly repeatable (0.31-0.44) (Kadel et al., 2006). Cattle that received a load score as balkers and non-balkers also received a scale score. Sixty-six percent of steers that received a chute score of 3 or greater balked, indicating that cattle reluctant to enter the chute were more active in the chute (Grandin, 1992).

Another measurement of activity in the scale is flight speed, which is the time that it takes for cattle to leave the scale and travel 1.83 meters. The time was recorded by an electric timing device. An increase in flight speed suggests that a calf taking more time to leave the scale was less stressed. However, a low, positive phenotypic correlation was found between flight speed and scale score (0.09) and flight speed was correlated with elevated cortisol levels (0.35). Over multiple flight speed measurements, flight speed increased regularly indicating that stress is reduced through repeated handling (Curley et al., 2006). Another study found flight speed to be negatively correlated with scale scores (-0.21 and -0.23). Flight speed had negative phenotypic correlations with meat water loss, Minolta scores, and tenderness (-0.05, -0.07, -0.04) and scale scores had low, negative phenotypic correlations with Minolta L and Minolta a (-0.06, -0.04) respectively, indicating that as flight speed and scale scores decrease meat quality improved (Kadel et al., 2006). Two cohorts of feedlot cattle had flight speeds recorded once a month for seven months, and flight speeds were averaged. Cattle with flight speeds less than 0.7 seconds were considered to be temperamental. Cattle considered temperamental had a lower average daily gain, weighed less at harvest, had lower carcass weights, more trim loss at the packing plant, but were leaner than those that had flight speed greater than 0.7 seconds. Average daily gain increased

from 0.79 kg/day for flight speeds of 0.5 seconds up to 0.93 kg/day at 1 second. Backfat increased from 8.6 mm to 10.2 mm, and carcass weight was 28 kg heavier (Burrow et al., 1997).

Pigs were given an activity score, based on a five point scale while they were in a scale during a performance test. The criteria for scoring were derived from those used in cattle. Pigs that had a lower activity score while in the scale were found to grow faster, and be fatter (Holl et al., 2010).

Vocal Score

Vocalization of the domestic pig is becoming an increasingly utilized measure of temperament. Vocal scores are a subjective score that quantifies the frequency and duration of vocalization that a pig expressed while stressed.

In a study to analyze acoustical vocalizations, light and electric shock were used as stressors. Pigs were subjected to light and electric shock, separately, six times at fifteen minute intervals. As pigs got used to the stressors their vocal responses decreased in frequency and duration. Type of stressor didn't affect the vocalization of the pigs (Dupjan et al., 2008).

During a human approach test vocalization was quantified as the response to human interaction. A group of three to five gilts were placed into a pen and a human stood in the corner of the pen. After a two minute initiation period a three minute period was monitored for vocalization, and a heart rate monitor was attached to the gilt during the test.

Vocalizations were recorded as single grunts, single squeals, and rapidly repeated grunts. Single grunts were the most common form of vocalization. Single grunts were negatively

correlated with human contact and positively correlated with locomotion. Gilts which squealed were quicker to approach and make contact with the human. Pigs that squealed had elevated heart rates. Frequency of the vocalizations coincides with reaction to the stressors (Marchant et al., 2001).

Recording temperament scores during a performance test in correspondence with measurement of performance traits is appropriate. Determining the relationships between temperament and performance traits included in selection programs is necessary to understand the effects selection for temperament will have on temperament and performance. Incorporating temperament scores into selection indices will be important with considerations for welfare.

BIOLOGICAL RESPONSE

The physiological response that a pig has to stress can cause growth performance to be stunted, and poorer carcass composition. The hypothalamus controls all endocrine hormonal responses, which controls metabolism and ingestive behaviors and play a large role in growth.

Cattle have increased hormone levels when subjected to stress. Cattle that had a higher scale score and faster flight speeds had a negative correlation with cortisol levels. As cattle became more reactive their cortisol levels decreased (Curley et al., 2006).

Ruis et al. (2000) subjected gilts to a backtest and scored pigs with more than four escape attempts as high restraint, and less than three escape attempts as low restraint. Gilts scored as low-restraint had higher mean scores of reactivity in the hypothalamic-pituitary-adrenocortical system, a negative-feedback system that stimulates hormonal production

during stress. Gilts that reacted more calmly to stress, had increased hormonal production. Pigs that react more calmly may be more capable of handling stress. Pigs that were low restraint in a backtest had higher levels of salivary cortisol than high resistant pigs (Geverink, 2002). While in a study by van Erp-van der Kooij et al. (2000) found that barrows resist less to a backtest than do gilts which is a trend throughout a pig's life. This may be due to lack of testosterone production in a male pig after castration.

Plasma catecholamine, prolactin, ACTH, and cortisol concentrations increased compared to initial levels when a pig lost a fight during a resident intruder test (D'Eath et al., 2002c). Pigs that squealed during a human approach test were considered to react more calmly to human presence. Pigs that squealed had elevated heart rates as a response to stress (Marchant et al., 2001).

Piglets are more susceptible to disease issues after being stressed, such as weaning or movement. Pigs were exposed to one of several stressors: four hours of shipping, heat stress, or cold stress. Pigs were also divided into three groups based on social status; dominant, intermediate, and submissive. All groups were subjected to all stressors. Submissive and intermediate pigs had increased plasma cortisol levels, increased globulin, and decreased weight gain, compared to dominant pigs. Pigs subjected to shipping grew slower. Pigs that were subjected to cold temperatures had increased natural killer cell toxicity, and decreased lymphocyte proliferation (Hicks et al., 1998).

Several studies have been conducted utilizing hormonal treatments in an attempt to reduce stress. Li et al. (2006) found that grow-finish pigs treated with tryptophan multiple times throughout the growth phase had improved behavior. Pigs with high levels of

tryptophan were more likely to avoid a stressful situation, but reactions to stressors, cortisol levels and heart rates were not changed. McGlone et al. (1988) treated pigs with andosterone to reduce level of agnostic behavior, competition or fighting. A treatment as low as half of a microgram reduced the level of aggressiveness and fighting in newly introduced pigs.

Biological responses to stress are considered to be indications of an animal's ability to cope with stress. Animals with increased hormonal response have reduced effects on performance as well as immune response. Pigs that respond to stress, better perform better than those that do not handle stress as well.

EFFECTS OF BREED AND SEX

Breed Differences

Response to heat stress is a form of temperament, and temperature has an effect on performance. Yorkshire sows were able to handle heat stress better than Large White sows (Bloemhof et al., 2008). Yorkshire sows had a higher number of total born and number born alive than Large White sows, even though Yorkshire sows were raised in warmer temperatures.

Landrace, Meishan, and Yorkshire pigs were exposed to heat, mixing and crowding stressors. Blood samples were taken to quantify cortisol concentrations and immune levels. Cortisol levels were three times higher in Meishan than Landrace, and Yorkshires were twice as high as Landrace. This indicates that Landrace were least capable of handling stress. Landrace also had lower levels of neutrophils, haptoglobin, and IgG indicating lowered immune response (Sutherland et al., 2006).

In a study done on a nucleus farm, Landrace pigs had a higher rate of tail-biting than did Large White pigs. Tail-biting was found to be negatively correlated with lean tissue growth and backfat levels (Breuer et al., 2005). A study of sow aggressiveness toward pigs between Dutch Landrace, Duroc and a Landrace x Duroc cross, found that Dutch Landrace sows had a higher rate of savaging their piglets compared to Duroc and crossbred sows (Knap and Merks, 1987).

Breed differences in temperament have been observed among cattle breeds. Charolais cattle visited the feed bunk more times per day, and spent more time eating than Angus and hybrid steers. Charolais cattle also had increased feed intake and average daily gain (Nkrumah et al., 2007). In a study quantifying flight speed and scale scores, eight breeds of cattle were evaluated. Limousin and Charolais cattle exited the scale faster than other breeds. Limousin cattle had the highest average scale scores of all breeds. Angus cattle took the longest leaving the scale, and had the lowest scale score (Burrow et al., 2000). A comparison of chute scores between *Bos indicus* and *Bos taurus* breeds of cattle revealed significant breed differences in temperament. *Bos indicus* cattle had an average chute score twice that of *Bos taurus* cattle. *Bos taurus* cattle also had greater average daily gain (Voisinet et al., 1997).

The National Pork Producer Council (2000) terminal line evaluation included a variety of breeds and terminal lines, but Durocs and Yorkshires were the only purebred lines. Durocs had a higher thickness of backfat, and took 5 fewer days to reach 113.4 kgs than Yorkshires. Durocs also had a lower carcass lean percent than Yorkshires but they did not differ in terms of loin muscle area. In a study by Hale et al. (1967) Duroc and Hampshire

barrows and gilts were fed and carcass measurements were taken. Durocs had a higher average daily gain, and were more efficient needing eight percent less feed per kg of gain. Hampshires were leaner and had a larger loin eye area. A study was conducted by Lo et al. (1992a) to measure differences in performance of pigs sired by Duroc and Landrace boars. Duroc sired pigs were 7.3 mm leaner, had 4.4 sq. cm. larger loin eye area, had 1.9 percent more intramuscular fat, and had 16.5 gm greater lean gain per day than pigs sired by Landrace boars. Miller et al. (1979) compared Duroc, Yorkshire, Hampshire, and all crosses were for differences in growth rate. Duroc pigs had higher pre-weaning and post-weaning average daily gain than both Yorkshire and Hampshire pigs. Durocs also required 4 fewer days than Hampshire to grow to 95 kg but one day more than Yorkshires. All of the F1 crosses, except for Yorkshire x Hampshire, grew faster than the purebreds, indicating the importance of knowing breed differences in performance for crossbreeding.

Purebred and two-way cross boars were mated to F1 females to produce three and four cross offspring. Pigs sired by Duroc boars grew to 100 kg faster than Yorkshire, Landrace, and Spotted boars mated to Yorkshire cross sows. Yorkshire and Landrace boars mated to Duroc cross sows grew faster than all other sires. Crossbred boars grew at an average of all sire breeds. Duroc sired pigs had the shallowest backfat depth, but pigs from Duroc cross sows sired by Yorkshire, Landrace and Spotted boars had the highest level of backfat (McLaren et al., 1987).

In a study quantifying heterosis and recombination effects for performance traits in pigs, breed differences were determined. Breed effects were calculated as comparisons to a base breed, Yorkshire for maternal breeds and Duroc for terminal breeds. In maternal lines

Landrace had a higher average daily gain and weighed more at off-test than Yorkshire and Chester White. Landrace were also leaner than Yorkshire and Chester White, but had small loin muscle area. Durocs grew faster than Hampshire and Pietrain, and had more backfat and smaller loin muscle area (Cassady et al., 2002).

Breeds significantly differ for both temperament and performance traits. Understanding the strengths and weakness of each breed for performance and temperament traits is important when designing a crossbreeding system.

Sex Differences

Feeding behavior directly affects growth of pigs. Barrows were found to make more trips to the feeder than boars or gilts. Barrows also spent more time at the feeder. Boars and barrows had a greater average daily gain than gilts along with higher average daily feed intake (Hyun et al., 1997). Tail-biting is a problem that affects the value of a marketed pig. Barrows were three times more likely to have their tails bitten than gilts and gilts were more likely to bite tails (Walker et al., 2006). In a study of the resident intruder test among young pigs, the sex of the pig didn't affect the likelihood of pigs attacking each other. However, sex of the opponent had an effect on intruder behavior. Of all residents that attacked, males were more likely to show aggression toward the intruder (Erhard et al., 1997). Cattle also demonstrate a sex difference in flight speed and chute scores. Steers took longer to exit the scale and also had a lower average chute score than heifers (Burrow et al., 2000). In another study involving chute scores in cattle, steers had a significantly lower average scale score than heifers (Voisinet et al., 1997).

Hale et al. (1967) found that barrows had larger average daily gain, greater backfat depth, smaller loin eye area, and lower dressing percent than did gilts. Gilts were also slightly more efficient (Hale et al., 1967). Steers that had a lower average chute score also had a higher average daily gain than heifers (Voisinet et al., 1997).

Differences in sexes for temperament and performance are notable in livestock. With swine genetics companies producing lines specific for reproductive performance and separate lines for terminal performance, the understanding of which breeds and sexes contribute temperament and performance is important.

GENETIC PARAMETERS

Heritability

Although heritability of temperament and behavior traits have not been as widely reported as those for performance traits, the heritability estimates reported range from low to high. Some temperaments can be attributed more to genetics of the animal, while some more to the environment. Understanding which measures can be influenced through selection is essential for selection programs.

The heritability of feeding behaviors varies between different measurements. Number of visits to the feeder (0.34) and feed intake per visit (0.27) were moderately heritable, while duration of visits, feeding rate, and time in feeder per day were lowly heritable (0.06-0.11) (Hall et al., 1999). Similar results were seen in a study of cattle feeding behavior. Heritability of feeding frequency (0.38) and feeding duration (0.28) were reported (Nkrumah et al., 2007).

When coping behaviors have been analyzed, varying results were found. A study involving the fear of humans, measured by bringing pigs to a stationary human, found that time to make contact with the human had a heritability of thirty seven percent, while time to approach the human (0.07) and time in contact (0.06) were lowly heritable (Hemsworth et al., 1990). In an open field test heritability ranged from (0.12-0.16) for the time it took a pig to approach an object (Beilharz and Cox, 1967).

Social behaviors such as tail-biting and feather pecking in poultry are heritable traits. Tail-biting is lowly heritable (0.05) in Landrace and Large White pigs (Breuer et al., 2005). Feather pecking in White Leghorn laying hens was found to be lowly heritable (0.05) for six week old birds, but highly heritable (0.38) at seventy weeks of age. Feather pecking was also moderately heritable (0.22) during fights (Kjaer et al., 1997).

Maternal behavior can be measured several ways. The aggressiveness of a sow toward her pigs or savaging of her pigs quantifies maternal behavior. Several studies have found a range in heritability for savaging. In a study of three different sow lines heritability ranged from 0.12-0.25 (Knap and Merks, 1987), while heritability for sow aggressiveness ranged from 0.13-0.22 (van der Steen et al., 1988), and heritability ranged from 0.17-0.24 in another study (Lovendahl et al., 2005). Crushing of piglets is also considered a measure of sow behavior and is lowly heritable (0.03) (Gade et al., 2006). The sow's reaction to a piglet's squeal has a heritability of 0.13 (Hellbrugge et al., 2006).

The heritability of temperament scores, mainly chute scores and flight speed have been calculated in cattle. Chute scores have been found to be lowly to moderately heritable 0.15-0.19 (Kadel et al., 2006), 0.30 (Burrow et al. 2000), and a range of 0.10-0.19

(Hearnshaw and Morris, 1984). Flight speed was also moderately heritable 0.30-0.34 (Kadel et al., 2006), 0.35 (Burrow et al., 2000), and in a few studies highly heritable 0.40-0.44 (Burrow, 2001), 0.49 (Nkrumah et al., 2007), and moderately heritable in swine 0.20 (Hansson et al., 2005). Scale activity scores in pigs were moderately heritable (0.23) (Holl et al., 2010). Temperament scores in dairy cattle have ranged in heritability from 0.40 (O'Blesness, et al., 1960) to 0.53 (Dickson et al., 1970).

Performance traits have been recorded for a longer period of time and heritability more commonly reported. Loin depth was highly heritable and ranged from 0.56 - 0.63, and backfat ranged from 0.23 - 0.31 (Siers and Thomson, 1972). Loin depth was only 13 percent heritable in another study, while backfat had a heritability of 0.45, percent lean muscle was heritable (0.43) and average daily gain was 19 percent heritable (van Wijk et al., 2005). In another study average daily gain had a heritability of 0.47, backfat was 72% heritable, and loin muscle area had a heritability of 0.45 (Suzuki et al., 2005). Backfat was found to be highly heritable at 0.54, and average daily gain was also highly heritable at 0.46 (Lo et al., 1992b). Finally the heritability of backfat has also been calculated as moderate to high ranging from 0.32 to 0.46, loin depth ranged from 0.19 to 0.31 (Zumbach et al., 2007). Heritability estimates were calculated during a terminal sire evaluation and estimates for backfat (0.46), percent lean (0.52), days to reach 113.4 kg (0.57), and loin muscle area (0.48), and were highly heritable (NPPC, 2000). A study by Stewart and Schinkel (1989) found that ultrasonic backfat was 41% heritable, loin muscle area was 47 percent heritable, and percent lean had a heritability of 0.48.

Genetic Correlations of Temperament and Performance

A study in persistence of pig temperament showed that pigs which are aggressive early in life tended to be more aggressive later in life, and during other temperament measures (D'Eath, 2002b). As expected animals that exhibit increased reactions to one stressor, are more likely to exhibit temperamental behavior in response to another stressor.

Kadel et al. (2006) found that flight speed in cattle was negatively and favorably correlated with chute scores ($r = -0.21$ to -0.23) meaning calmer cattle in the chute exited the chute more slowly. Phocas et al. (2006) found that aggression score was genetically correlated with the number of escape attempts in cattle. Aggression toward a handler was highly, positively correlated ($r = 0.84$) with escape attempts suggesting that selection for less aggressive cattle, should lead to fewer escape attempts and easier handling. Although genetic correlations were not estimated, cattle scored for loading behavior were more likely to be active in a chute, and this behavior was found to be persistent during repetition of scoring (Grandin, 1992). Results suggest that animals that are temperamental for one trait potentially will exhibit negative behavior for another.

Feeding behavior traits are moderately correlated with performance traits. As number of visits to the feeder increased, backfat and average daily gain are expected to decrease. However, backfat and average daily gain were both positively correlated with total time spent feeding (Hall et al., 1999).

In a herd comprised of Limousin cattle, a docility test was performed to determine genetic relationships with breeding traits. Docility was highly and favorably correlated with fertility, as docility increased so did fertility. Docility was lowly correlated with calving

weight and milk yield allowing selection on docility without affecting those traits. Docility was negatively correlated with age at puberty however, indicating more docile cattle take longer to reach puberty (Phocas et al., 2006).

The scale activity score was found to have low to moderate correlations with weight and backfat, ranging from -0.11 to -0.38. As scale activity score increases pigs tend to weigh less and are leaner. Selection for more docile pigs should result in fatter, faster growing animals (Holl et al., 2010).

Flight speed in pigs had a moderate, positive, and favorable correlation with average daily gain, but was positively and unfavorably correlated with backfat. An increase in flight speed (increase in time to leave chute) suggests a more relaxed animal. As flight speed increases backfat increases, suggesting calmer animals are fatter (Hansson et al., 2005). Flight speed in cattle was also moderately and positively correlated with tenderness and meat color. Scale scores were negatively but favorably correlated with the same meat quality traits (Kadel et al., 2006).

In another study, flight speed was found to be positively correlated with feed conversion, highly correlated with growth efficiency, and negatively correlated with feed intake. Cattle that have higher flight speeds are calmer, eat less, and are more efficient (Nkrumah et al., 2007).

Temperament measures are variable in their correlation, favorable and unfavorable, with reported performance traits. Understanding the relative value of performance traits and temperament traits will be important when deciding which temperament traits can be incorporated into a breeding program. Determining if selection for improved temperament

will improve or impair performance is important, along with knowing if selection for performance will improve or impair temperament.

Correlations between Performance Traits

The relationship between performance traits is important in selection programs. Understanding how selection for one trait will affect the performance of another determines how selection criteria are weighted for each trait. Selection for certain traits may earn more money at slaughter, but may have a negative effect on growth, which could cost a producer more in return.

Phenotypic relationships were determined for a variety of performance traits in the National Pork Producer Council's terminal sire evaluation (2002). Days to 113.4 kg had a correlation ($r = 0.02$) near zero with loin muscle area, and low but favorable correlation ($r = -0.04$) with backfat. Phenotypic correlations between backfat and loin muscle area were negative and favorable ($r = -0.49$).

Genetic covariance estimates for performance traits through the terminal sire evaluation done by the National Pork Producer Council (2000) found backfat at the tenth rib had a negative, favorable correlation ($r = -0.61$) with loin muscle area and a correlation ($r = -0.05$) that was near zero with days to 113.4 kg. The correlation between days to 113.4 kg and loin muscle area was near zero ($r = 0.05$) and unfavorable. Reports of correlations between backfat and percent lean were high and favorable ($r = -0.87$), the correlation between percent lean and loin muscle area was ($r = 0.65$), and the correlation between backfat and loin muscle area ($r = -0.38$) were favorable (Stewart and Schinkel, 1989). The estimate between age to 103.6 kg and ultrasound backfat was low ($r = -0.13$) in another study by Lo et al. (1992b).

Many performance traits are favorably correlated, and improvement through selection of one trait will result in improved performance in another. However, selection for increased leanness has resulted in slower growth rate.

STATISTICAL ANALYSIS

Phenotypic Analysis

The relationships between traits must be understood to determine the effects of selection based on certain traits. The phenotypic relationships provide information about the reaction one trait will have to the change in another animal's phenotype.

A common method of calculating phenotypic relationships is with Pearson correlation coefficients. A Pearson correlation calculates the linear relationship between traits. The Pearson correlations between several behavior traits, the human approach, open door, and novel object tests, were calculated (van Erp-van der Kooij et al., 2002).

Determining the significance of effects on different traits is done with the GLM or MIXED procedure of SAS (SAS Inst., Inc. Cary, NC). Both procedures fit linear models to the data to allow statistical inferences to be made. Data is assumed to be normally distributed, and calculates means, variances and co-variances for the model. The GLM and MIXED procedures allow for analyses of unbalanced data sets. The MIXED procedure fits the models you select by restricted maximum likelihood, similar to many genetic analysis procedures. The MIXED procedure allows for the inclusion of random effects.

The analysis of categorical values can be better done utilizing the LOGISTIC procedure of SAS (SAS Inst., Inc. Cary, NC). The LOGISTIC procedure fits linear regression models for discrete response data by restricted maximum likelihood. The logistic

procedure is useful for categorical traits and data with no natural ordering (Taberner et al., 2008). The procedure operates using a logit function to estimate the parameters of the categorical data by doing a log transformation on each trait during analysis. Contrasts can also be performed and the comparison is reported as an odds ratio. Contrasts of least squares means have been used as a way to compare means (Cassady, 2007), and would be useful in breed and sex comparisons.

Genetic Parameters

Heritability and genetic correlations are arguably the most valuable information when determining which traits to use in selection. Knowing how they affect the performance of other traits is essential. When the amount of pedigree data allows for the construction of in depth relationships, the maximum likelihood method is the most reasonable option (Falconer and Mackay, 1996). Restricted maximum likelihood (REML) is an accountable method to use as it accounts for some biases of other methods, by adjusting observations for the estimates of the fixed effects.

Multiple trait derivative-free maximum likelihood (MTDFREML) estimates the variance components of traits using the derivative free method. Although the name of the software includes the words multiple trait, it also performs single trait analysis.

MTDFREML is very useful software used to estimate the heritability and correlations of traits in which all animals in the pedigree do not have performance records (Boldman et al., 1995).

A similar program is the average information restricted maximum likelihood (AIREML). AIREML, which uses the average information from a data set. When using a

large amount of data AIREML is useful. The program uses a matrix with the average information and uses restricted maximum likelihoods to calculate heritability, correlations, variance and covariance components (Ashida and Iwaisaki, 1998). AIREML allows categorical traits to be analyzed along with linear traits. Body condition scores were analyzed with other dairy production traits to determine heritabilities and correlations using AIREML (Dechow et al., 2001).

Gianola (1979) found that heritability estimates for categorical traits, with an underlying quantitative genetic component, were determined to be greater using a threshold model than a linear model. More recently, Bayesian statistical methods have become a popular method for determining genetic parameters. The program GIBBSF90 utilizes Gibbs sampling to calculate variance components of continuous traits. It was used for estimates of growth in Gelbvieh cattle (Iwaisaki et al., 2005). The values from the Gibbs sampler are highly correlated (.99) with the values calculated by MTDFREML (Van Tassell and Van Vleck, 1996). This program requires a large amount of data to allow a burn in procedure, but is computationally efficient. The Gibbs sampling procedure allows for the analysis of categorical data such as calving still birth or calving ease on over 184,000 records (Hansen et al., 2004).

Analysis for a threshold-linear model in which number born alive and number born dead were analyzed as categorical traits, and backfat and age were analyzed as continuous traits, was done using THRGIBBSF90. This program estimates (co)variance components and genetic parameters in models with categorical and continuous traits (Lee et al., 2002). A similar program that is easier to use is THRGIBBS1F90 (Tsuruta and Misztal, 2006).

POSTGIBBSF90 (Misztal et al., 2002) was used then to calculate posterior means, standard deviations, and credible regions. In a study of piglet survival Arango et al. (2005) used a chain of 200,000 cycles with a burn-in period of 20,000 iterations was used storing every 20th sample. This allowed for nine thousand samples to be available to calculate the posterior means.

THRGIBBSF90 was again used for the analysis of genetic parameters for preweaning mortality and birth weight in piglets (Arango et al., 2006). The study used birthweight as a continuous trait and preweaning mortality, stillborns, and late-stage mortality as categorical traits. The analysis was run with 250,000 single chain cycles with a 10,000 cycle burn-in period. POSTGIBBSF90 was again used to calculate posterior statistics.

The pedigree relationships utilized by all of these programs allow for connections between animals and predictions to be made even if records aren't available for all the animals in the pedigree.

CONCLUSION

With the recent interest for alternative swine housing options, the methods in which we raise and select pigs will change. Housing and handling procedures are becoming more scrutinized and breeding pigs that can handle differing environments is important. However, the pork producer's profits are more directly affected by performance of the pigs they produce than how those pigs react in a stressful situation. Value of a temperament or behavior score to the producer is limited if it negatively affects performance, and quantifying the relationship temperament has with performance is key.

Recently studies of pig behavior have become more relevant to the industry resulting in more studies being performed, and more results being published. Maternal behavior has been studied as a way to minimize piglet death through modifying the sow's behavior. Sows that were highly active, standing often, were more likely to crush piglets than sows that lay down for longer periods of time (Rydhmer, 2000). A sow that reacted more aggressively toward the sound of a stressed piglet was more likely to injure a pig (Lovendahl et al., 2005). Sows that showed aggression toward their piglets resulted in a loss of two more pigs per lactation than sows that were not aggressive toward their pigs (Knap and Merks, 1987).

Feeding behavior can also have an effect on performance. Pigs that ate faster grew faster (Rauw et al., 2006), and pigs that had less competition at the feeder grew faster (Georgsson et al., 2002). Social behavior of pigs can affect growth and value of the pig. In recorded fights, pigs that won grew faster, and had a lower mortality rate than those that lost fights (Hartsock et al., 1977). Tailbiting is a social behavior that can cause dramatic profit reductions when pigs are marketed, and the bigger, more productive pigs are most likely the recipients of tailbiting (Walker et al., 2006).

Behavior or temperament is considered a pig's response to stress. A pig that reacts strongly to stress may be more suitable for production than one that is not reactive. In a study where pigs were subjected to the backtest; pigs that struggled more had increased average daily gain (Cassady, 2007). Pigs that struggled more also had increased carcass weight, and increased percent lean growth (Hessing et al., 1994). Increased reactivity of these pigs also resulted in increased profits for the producer. Response to mixing pigs, using the resident intruder test, found pigs that were more aggressive were leaner (Cassady, 2007).

In the human interaction test, gilts that spent more time in contact with the human, had increased farrowing rates and required fewer matings per litter farrowed. Gilts in contact also grew faster (Hemsworth et al., 1990). Scale score is a measure of an animal's temperament and it is related to performance. Pigs selected for calmer temperament are expected to grow faster and be fatter (Holl et al., 2010). Cattle that were calmer in the chute grew faster than cattle that were more active in the chute (Voisinet et al., 1997), and cattle that were more active weighed less than calm cattle (Burrow et al., 2000).

The relationship between temperament and performance is important and quantifiable. Utilizing the correct measure of temperament taken at the correct time is important as well. Use of temperament scores in selection may not directly result in profit, but could improve production efficiency, animal well-being, and animal handling.

LITERATURE CITED

- Arango, J., I. Misztal, S. Tsuruta, M. Culbertson, W. Herring. 2005. Threshold-linear estimation of genetic parameters for farrowing mortality, litter size, and test performance of Large White sows. *Journal of Animal Science* 83: 499-506.
- Arango, J., I. Misztal, S. Tsuruta, M. Culbertson, J.W. Holl, W. Herring. 2006. Genetic study of individual preweaning mortality and birth weight in Large White piglets using threshold-linear models. *Livestock Science* 101: 208-218.
- Ashida, I., H. Iwaisaki. 1998. A numerical technique for REML estimation of variance components using average information algorithm and its computing property. *Animal Genetics* 69: 631-636.
- Beilharz, R.G., and D.F. Cox. 1967. Genetic Analysis of Open Field Behavior in Swine. *Journal of Animal Science* 26: 988-990.
- Bloemhof, S., E.H. van der Waaij, J.W.M. merks, and E.F. Knol. 2008. Sow line differences in heat stress tolerance expressed in reproductive performance traits. *Journal of Animal Science* 86: 3330-3337.
- Boldman, K.G., L.A. Kriese, L.D. Van Vleck, and S.D. Kachman. 1995. A manual for MTDFREML. A set of programs to obtain estimates of variance and covariances. U.S. Department of Agriculture, Agricultural Research Service.
- Breuer, K., M.E.M. Sutcliffe, J.T. mercer, K.A. Rance, N.E. O'Connell, I.A. Sneddon, and S. A. Edwards. 2005. Heritability of clinical tail-biting and its relation to performance traits. *Livestock Production Science* 93: 87-94.
- Burrow, H.M., and R.D. Dillon. 1997. Relationships between temperament and growth in a feedlot and commercial carcass traits of Bos indicus crossbreds. *Australian Journal of Experimental Agriculture* 37: 407-411.
- Burrow, H.M., and N.J. Corbet. 2000. Genetic and environmental factors affecting temperament of zebu and zebu-derived beef cattle grazed at pasture in the tropics. *Australian Journal of Experimental Agriculture* 51: 155-162.
- Burrow, H.M. 2001. Variances and covariance between productive and adaptive traits and temperament in a composite breed of tropical beef cattle. *Livestock Production Science* 70: 213-233.
- Cassady, J.P., L. D. Young and K. A. Leymaster. 2002. Heterosis and recombination effects on pig growth and carcass traits. *Journal of Animal Science* 80: 2286-2302.

- Cassady, J.P. 2007. Evidence of phenotypic relationships among behavioral characteristics of individual pigs and performance. *Journal of Animal Science* 85: 218-224.
- Curley, K.O., J.C. Paschal, T.H. Welsh, and R.D. Randel. Technical note: Exit velocity as a measure of cattle temperament is a repeatable and associated with serum concentration of cortisol in Brahman bulls. *Journal of Animal Science* 84: 3100-3103.
- D'Eath, R.B., and C.C. Burn. 2002a. Individual differences in behavior: A test of 'Coping style' does not predict resident-intruder aggressiveness in pigs. *Behaviour* 139: 1175-1194.
- D'Eath, R.B. Individual aggressiveness measured in a resident-intruder predicts the persistence of aggressive behaviour and weight gain of young pigs after mixing. 2002b. *Applied Animal Behaviour Science* 77: 267-283.
- D'Eath, R.B., Pickup, Helena. 2002c. Behaviour of young growing pigs in a resident-intruder test designed to measure aggressiveness. *Aggressive Behaviour* 28: 401-415.
- D'Eath, R.B., and A.B. Lawrence. 2004. Early life predictors of the development of aggressive behaviour in the domestic pig. *Animal Behaviour* 67:501-509.
- Dechow, C.D., G.W. Rogers, and J.S. Clay. 2001. Heritabilities and correlations among body condition scores, production traits, and reproductive performance. *Journal of Dairy Science* 84: 266-275.
- Dickson, D.P., G.R. Barr, L.P. Johnson, and D.A. Wiekert. 1970. Social dominance and temperament in dairy cows. *Journal of Dairy Science* 53: 904.
- Dupjan, S., P.C. Schon, B. Puppe, A. Tuscherer, and G. Manteuffel. 2008. Differential vocal responses to physical and mental stressors in domestic pigs. *Applied Animal Behaviour Science* 114: 105-115.
- Erhard, H.W., M. Mendl, and D.D. Ashley. 1997. Individual aggressiveness of pigs can be measured and used to reduce aggression after mixing. *Appl. Anim. Behav. Sci.* 45: 31-42.
- Falconer, D.S., and T.F.C Mackay. 1996. *Introduction to Quantitative Genetics*. 4 ed. Pearson Prentice Hall, New York.
- Forkman, B., A. Boissy, M. C. Meunier-Salauun, E. Canali, and R. B. Jones. 2007. A critical review of fear tests used on cattle, pigs, sheep, poultry and horses. *Physiol. and Behav.* 92: 340-374.

- Gade, S., J. Bennewitz, K. Kirchner, H. Looft, P.W. Knap, and E. Kalm. 2006. Genetic parameters for behaviour traits in sows. Presented at 8th World Congress of Genetics Applied to Livestock Production Aug. 2006.
- Georgsson, L. and J. Svendsen. 2002. Degree of competition at feeding differentially affects behavior and performance of group-housed growing-finishing pigs of different relative weights. *Journal of Animal Science* 80: 376-383.
- Geverink, N.A., S.G.P. Schouten, G. Gort, V.M. Wiegant. 2002. Individual differences in aggression and physiology in peri-pubertal breeding gilts. *Applied Animal Behaviour Science* 77: 43-52.
- Gianola, D. 1979. Heritability of polychotomous characters. *Genetics* 93: 1051-1055.
- Gill, J.C., and W. Thomson. 1955. Observations on the behavior of suckling pigs. *British Journal of Animal Behavior* 4: 46.
- Giroux, S., G.P. Martineau, S. Robert. 2000. Relationships between individual behavioural traits and post-weaning growth in segregated early-weaned piglets. *Applied Animal Behaviour Science* 70: 41-48.
- Grandin, T. 1992. Behavioral agitation during handling of cattle is persistent over time. *Applied Animal Behaviour Science* 36: 1-9.
- Grandin, T. 1994. Solving livestock handling problems. *Vet. Med.* 89: 989-998.
- Grandin, T., and M. J. Deesing. 1998. Genetics and behavior during handling, restraint, and herding. In: Grandin, T. (ed.), *genetics and the behavior of domestic animals*. Academic Press, San Diego, USA, pp. 113-144.
- Graves, H.B. 1984. Behavior and Ecology of Wild and Feral Swine (*Sus Scrofa*). *Journal of Animal Science* 58: 482-492.
- Hale, O.M., B.L. Southwell. 1967. Differences in Swine Performance and Carcass Characteristics because of Dietary Protein Level, Sex and Breed. *Journal of Animal Science* 26: 341-344.
- Hall, A.D., W.G. Hill, P.R. Bampton, and A.J. Webb. 1999. Genetic and phenotypic parameter estimates for feeding pattern and performance test traits in pigs. *Journal of Fundamental and Applied Research*. 68: 43-48.
- Hansen, M., M.S. Lund, J. Pedersen, and L.G. Christensen. 2004. Gestation length in Danish Holsteins has weak genetic associations with stillbirth, calving difficulty, and calf size. *Livestock Production Science* 91: 23-33.

- Hansson, A.C., R.E. Crump, H.U. Graser, and R. Sokolinski. 2005. Relationships among temperament and production traits of pigs. *Advancement of Animal Breeding and Genetics* 25: 141-148.
- Hartsock, T.G., H.B. Graves, and B.R. Baumgardt. 1977. Agonistic Behavior and the Nursing Order in Suckling Piglets: Relationships with Survival, Growth, and Body Composition. *Journal of Animal Science* 44: 320-330.
- Hartsock, T.G. 1982. Behavioral responses to management systems- Swine. In: W. Woods (Ed.) *Proc of the Symposium on Management of Food Producing Animals*. pp 185-193.
- Hearnshaw, H., and C.A. Morris. 1984. Genetic and Environmental Effects on a Temperament Score in Beef Cattle. *Australian Journal of Agricultural Research* 35: 723-733.
- Hellbrugge, B., K.H. Tolle, J. Bennewitz, U. Presuhn, and J. Krieter. 2006. Genetic parameters of mothering ability in sows and its relation to piglet mortality traits. Presented at 8th World Congress of Genetics Applied to Livestock Production Aug. 2006.
- Hemsworth, P.H., J.L. Barnett, D. Treacy, and P. Madgwick. 1990. The Heritability of the Trait Fear of Humans and the Association Between This Trait and Subsequent Reproductive Performance of Gilts. *Applied Animal Behaviour Science* 25: 85-95.
- Hessing, M.J.C., W.G.P. Schouten, P.R. Wiepkema, M.J.M. Tielen. 1994. Implications of individual behavioral characteristics on performance in pigs. *Livestock Production Science* 40: 187-196.
- Hicks, T.A., J.J. McGlone, C.S. Whisnant, H.G. Kattesh, and R.L. Norman. 1998. Behavioral, endocrine, immune, and performance measures for pigs exposed to acute stress. *Journal of Animal Science* 76: 474-483.
- Holl, J.W., G.A. Rohrer, and T.M. Brown-Brandl. 2010. Estimates of genetic parameters among scale activity scores, growth, and fatness in pigs. *Journal of Animal Science* 88: 455-459.
- Hyun, Y., M. Ellis, F.K. McKeith, and E.R. Wilson. 1997. Feed intake pattern of group-housed growing-finishing pigs monitored using a computerized feed intake recording system. *Journal of Animal Science* 75: 1443-1451.

- Iwaisaki, H., S. Tsuruta, I. Misztal and J. K. Bertrand. 2005. Genetic parameters estimated with multitrait and linear spline-random regression models using Gelbvieh early growth data. *Journal of Animal Science* 83: 757-763.
- Jarvis, S., R.B. D'Eath, and K. Fujita. 2005. Consistency of piglet crushing by sows. *Animal Welfare* 14: 43-51.
- Kadel, M.J., D.J. Johnston, H.M. Burrow, H. Graser, and D.M. Ferguson. 2006. Genetics of flight time and other measures of temperament and their value as selection criteria for improving meat quality traits in tropically adapted breeds of beef cattle. *Australian Journal of Agricultural Research* 57: 1029-1035.
- Kanis, E., K.H. De Greef, A. Hiemstra, and J.A.M. van Arendonk. 2005. Breeding for societally important traits in pigs. *Journal of Animal Science* 83:948-957.
- Kjaer, J.B., and P. Sorensen. 1997. Feather pecking behaviour in White Leghorns, a genetic study. *British Poultry Science* 38: 333-341.
- Knap, P.W., and J.W.M. Merks. 1987. A Note on the Genetics of Aggressiveness of Primiparous Sows Toward their Piglets. *Livestock Production Science* 17: 161-167.
- Lee, D., I. Misztal, J.K. Bertrand, and R. Rekaya. 2002. National evaluation of calving ease, gestation length and birth weight by linear and threshold model methodologies. *Journal of Applied Genetics* 43: 209-216.
- Le Neindre, P., X. Boivin, and A. Boissy. 1996. Handling of extensively kept animals. *Appl. Anim. Behav. Sci.* 49: 73-81.
- Levine, S., and S.G. Wiener. 1989. *Coping with uncertainty: A paradox*. Academic Press, New York.
- Lewis, J.C. 1966. Observations of pen-reared European hogs released for stocking. *Journal Wildlife Management* 30: 832.
- Li, Y.Z., B.J. Kerr, M.T. Kidd, and H.W. Gonyou. 2006. Use of supplementary tryptophan to modify the behavior of pigs. *Journal of Animal Science* 84: 212-220.
- Lo, L.L., D.G. McLaren, F.K. McKeith, R.L. Fernando, and J. Novakofski. 1992a. Genetic analyses of growth, real-time ultrasound, carcass, and pork quality traits in Duroc and Landrace pigs: Breed effects. *Journal of Animal Science* 70: 2387-2396.
- Lo, L.L., D.G. McLaren, F.K. McKeith, R.L. Fernando, and J. Novakofski. 1992b. Genetic analyses of growth, real-time ultrasound, carcass, and pork quality traits in Duroc and

- Landrace pigs II: Heritabilities and correlations. *Journal of Animal Science* 70: 2373-2386.
- Lovendahl, P., L.H. Damgaard, B.L. Nielsen, K. Thodberg, G. Su, and L. Rydhmer. (2005). Aggressive behaviour of sows at mixing and maternal behaviour are heritable and genetically correlated traits. *Livestock Production Science* 93:73-85.
- Marchant, J.N., X. Whittaker, and D.M. Broom. 2001. Vocalisations of the adult female domestic pig during a standard human approach test and their relationships with behavioural and heart rate measures. *Applied Animal Behaviour Science* 72: 23-39.
- McLaren, D.G., D.S. Buchanan, and R.K. Johnson. 1987. Growth Performance for Four Breeds of Swine: Crossbred Females and Purebred and Crossbred Boars. *Journal of Animal Science* 64: 99-108.
- McGlone, J.J. 1991. Techniques for evaluation and quantification of pig reproductive, ingestive, and social behaviors. *Journal of Animal Science* 69: 4146-4154.
- McGlone, J.J., and J.L. Morrow. 1988. Reduction of Pig Agnostic Behavior by Andosterone. *Journal of Animal Science* 66: 880-884.
- Miller, H.W., M.F. Cain, and H.D. Chapman. 1979. Performance of Purebred and Crossbred Pigs. *Journal of Animal Science* 49: 943-949.
- Misztal, I., S. Tsuruta, T. Strabel, B. Auvray, T. Druet, and D. H. Lee. 2002. BLUPF90 and related programs (BGF90). Communications No. 28-07 in Proc. 7th World Cong. Genet. Appl. Livestock Production., Montpellier, France.
- Nkrumah, J.D., D.H. Crews, J.A. Basarab, M.A. Price, E.K. Okine, Z. Wang, C. Li, and S.S. Moore. 2007. Genetic and Phenotypic relationships of feeding behavior and temperament with performance, feeding efficiency, ultrasound, and carcass merit of beef cattle. *Journal of Animal Science* 85: 2382-2390.
- NPPC. 2000. Genetic Evaluation, Terminal Line Program Results. R. Goodwin and S. Burroughs, ed. Natl. Pork Prod. Council, Des Moines, IA.
- O'Blesness, G.V., L.D. Van Vleck, and C.R. Henderson. 1960. Heritabilities of some type appraisal traits and their genetic and phenotypic correlations with production. *Journal of Dairy Science* 42: 1490-1498.
- Phocas, F., X. Boivin, J. Sapa, G. Trillat, A. Boissy, and P. Le Neindre. 2006. Genetic correlations between temperament and breeding traits in Limousin heifers. *Animal Science* 82: 805-811.

- Quiniou, N., S. Dubois, J. Noblet. 2000. Voluntary feed intake and feeding behaviour of group housed growing pigs are affected by ambient temperature and body weight. *Livestock Production Science* 63: 245-253.
- Rauw, W.M., J. Soler, J. Tibau, J. Reixach, and L. Gomez Raya. 2006. Feeding time and feeding rate and its relationship feed intake, feed efficiency, growth rate, and rate of fat deposition in growing Duroc barrows. *Journal of Animal Science* 84: 3403-3409.
- Reale, D., S.M. Reader, D. Sol, P.T. McDougall, and N.J. Dingemanse. 2007. Integrating animal temperament within ecology and evolution. *Biological Reviews* 82: 291-318.
- Ruis, M.A., Joop H.A. te Brake, Johan A. van de Burgwal, Ingrid C. de Jong, Harry J. Blokhuis, and Jaap M. Koolhaas. 2000. Personalities in female domesticated pigs: behavioural and physiological indications. *Applied Animal Behavior Science* 66: 31-47.
- Rydhmer, L. 2000. Genetics of sow reproduction, including puberty, oestrus, pregnancy, farrowing, and lactation. *Livestock Production Science* 66: 1-12.
- Sekiguchi, T., and Y. Koketsu. 2004. Behavior and reproductive performance by stalled breeding females on a commercial swine farm. *Journal of Animal Science* 82: 1482-1487.
- Siers, D.G., and G.M. Thomson. 1972. Heritabilities and Genetic Correlations of Carcass and Growth Traits in Swine. *Journal of Animal Science* 35: 311-316.
- Sih, A., A. Bell, and J.C. Johnson. 2004. Behavioral syndromes: An ecological and evolutionary overview. *Trends in Ecology and Evolution* 19: 372-378.
- Stewart, T.S., and A.P. Schinkel. 1989. Genetic parameters for swine growth and carcass traits. In: Young, L.D. (ed.) *Genetics of Swine*. USDA-ARS, Clay Center, Nebraska, pp. 77-79.
- Sutherland, M.A., S.R. Niekamp, S.L. Rodriguez-Zas, and J.L. Salak-Johnson. 2006. Impacts of chronic stress and social status on various physiological and performance measures in pigs of different breeds. 2006. *Journal of Animal Science* 84: 588-596.
- Suzuki, K., M. Irie, H. Kadowaki, T. Shibata, M. Kumagai, and A. Nishida. 2005. Genetic parameter estimates of meat quality traits in Duroc pigs selected for average daily gain, longissimus muscle area, backfat thickness, and intramuscular fat content. *Journal of Animal Science* 83: 2058-2065.
- Taberner, E., A. Medrano, A. Pena, T. Rigau, and J. Miro. 2008. Oestrus cycle characteristics and prediction of ovulation in Catalanian jennies. *Theriogenology* 70: 1489-1497.

- Tanaka, Y., Y. Koketsu. (2007). A Field Study of the Associations between Behaviors and Reproductive Performance in Lactating Sows. *Journal of Veterinary Medicine Science* 69: 1229-1233.
- Thodberg, K., K.H. Jensen, M.S. Herskin. 1999. A general reaction pattern across situations in prepubertal gilts. *Applied Animal Behaviour Science* 63: 103-119.
- Tsuruta, S., and I. Misztal. 2006. THRGIBBS1F90 for estimation of variance components with threshold and linear models. Communication No. 27-31 in Proc 8th World Cong. Genet. Appl. Livestock Production, Belo Horizonte, Minas Gerais, Brazil.
- Turner, S.P., I.M.S. White, S. Brotherstone, M.J. Farnsworth, P.W. Knap, P. Penny, M. Mendly, and A.B. Lawrence. 2006. Heritability of post-mixing aggressiveness in grower-stage pigs and the relationship between aggressiveness and production traits. *Animal Science* 82: 615-620.
- Van der Steen, H.A.M., L.R. Schaeffer, H. de Jong, and P.N. de Groot. (1988). Aggressive Behavior of Sows at Parturition. *Journal of Animal Science* 66: 271-279.
- Van Erp-van der Kooij, E., A.H. Kuijpers, J.W. Schrama, F.J.C.M van Eerdenburg, W.G.P. Schouten, and M.J.M. Tielen. 2002. Can we predict behaviour in pigs? Searching for consistency in behaviour over time and across situations. *Applied Animal Behaviour Science* 75: 293-305.
- Van Erp-van der Kooij, E., A.H. Kuijpers, F.J.C.M. van Eerdengurg, and M.J.M. Tielen. 2003. Coping characteristics and performance in fattening pigs. *Livestock Production Science* 84: 31-38.
- Van Tassell, C.P., L.D. Van Vleck. 1996. Multiple-trait Gibbs sampler for animal models: flexible programs for Bayesian and likelihood-based (co)variance component inference. *Journal of Animal Science* 74: 2586-2597.
- van Wijk, H.J., D.J.G. Arts, J.O. Matthews, M. Webster, B.J. Ducro, and E.F. Knol. 2005. Genetic parameters for carcass composition and pork quality estimated in a commercial production chain. *Journal of Animal Science* 83: 324-333.
- Voisinet, B.D., T. Grandin, J.D. Tatum, S.F. O'connor, and J.J. Struthers. 1997. Feedlot cattle with calm temperaments have higher average daily gains than cattle with excitable temperaments. *Journal of Animal Science* 75: 892-896.
- Walker, P.K., G. Bilkei. 2006. Tail-biting in outdoor pig production. *The Veterinary Journal* 171: 367-369.

- Warriss, P.D., S.N. Brown, P.B. Gade, C. Santos, L.N. Costa, E. Lambooij, and R. Geers. 1998. An analysis of data relating to pig carcass quality and indices of stress collected in European Union. *Meat Science* 49: 137-144.
- Zumbach, B., I. Mistzal, S. Tsuruta, J. Holl, W. Herring, and T. Long. 2007. Genetic correlations between two strains of Durocs and Crossbreds from differing production environments for slaughter traits. *Journal of Animal Science* 85: 901-908.

CHAPTER 2

BREED DIFFERENCES IN PIG TEMPERAMENT AND ITS PHENOTYPIC RELATIONSHIP WITH PERFORMANCE

ABSTRACT

Nucleus populations of Chester White (CW), Duroc (D), Landrace (L), and Yorkshire (Y) boars and gilts (n=4,774) were used to estimate breed differences in temperament and its relationship with performance. Adjusted backfat (BF), adjusted loin depth (LD), days to 113.4 kilograms (DAYS), estimated percent fat-free lean (LEAN), and three temperament scores: load score (LS), scale score (SS), and vocal score (VS) were recorded. All temperament scores ranged from 1(calm) to 5(highly excited). Load score was recorded during loading into a scale; SS and VS were recorded while in the scale as ultrasound measurements were taken. Temperament scores were evaluated as categorical traits with a statistical model including fixed effects of breed, sex, contemporary group (barn-farm-test date), and off-test weight as a covariate. Order that a pig was loaded into the scale was included in the model for LS. After initial analysis, it was determined that VS was best described as two categories, vocal or non-vocal, and was reanalyzed accordingly. Statistical models for BF, LD, DAY, and LEAN included fixed effects of breed, sex, and LS, SS, or VS. Growth rate was adjusted to 113.4 kilograms, while BF and LD were adjusted to 113.4 kg through regression on mean off-test weight of respective breed. Breed differences for LS, SS, and VS were estimated as odds ratios. The odds of higher LS were greater for L (1.62, 1.30; $P < 0.01$) than D and Y respectively. Landrace had a greater ($P < 0.01$) probability of a higher SS and VS compared to CW (1.77, 2.37), D (3.31, 3.94) and Y (2.51, 2.46). Yorkshire had greater ($P < 0.01$) odds of increased LS (1.25), SS (1.32), and VS (1.60) than D. Chester White had greater odds of increased LS and SS than D (1.58, 1.87) and Y (1.26, 1.42), respectively. Chester White were 1.66 ($P < 0.01$) times more likely to have a higher VS than

D. Pearson's correlations ($P < 0.01$) for SS with LS, VS, BF, LD, DAYS, and LEAN were 0.13, 0.32, -0.15, -0.07, 0.10 and 0.17, respectively. Pearson's Correlations for VS with BF, DAYS, and LEAN were -0.05, 0.05, and 0.08 respectively. Landrace were more excited and vocal in the scale than CW, D and Y. Landrace were more difficult to load into the scale than D and Y. Chester White were more active in the scale than D and Y, and more vocal than D. Yorkshire were harder to load, more active, and more vocal than D. Pigs with lower temperament scores were fatter, had greater loin depth and grew faster.

Key words: pigs, breeds, performance, temperament

INTRODUCTION

Integration of the pork industry has led to fewer, larger producers and more standardized production environments across the industry. This has resulted in fewer producers who manage more pigs which in turn results in reduced pig to producer contact, decreasing the opportunity for pigs to become familiar with humans, and creating the potential for pigs to relate handling with stress (Le Neindre et al., 1998). There is also increasing public concern for the pig's welfare in confinement. Changes are starting to occur in pig housing to better account for the animal's welfare, especially in sow housing.

Better understanding of pig temperament may lead to increased performance, increased ease of handling, and increased production efficiency. However, temperament or behavior of the pig is generally over-looked in order to obtain the best performing pigs. A number of methods have been previously developed to test temperament in order to quantify the relationship it has with performance, and its effect on production. Many tests are done when pigs are younger, and easy to handle, such as the backtest and resident intruder test (Cassady, 2007). Few tests have been developed to test the temperament of pigs during performance testing which is a common handling procedure in the swine industry. Previous studies quantified cattle activity in a chute (Grandin, 1994; Voisinet et al., 1997) and pig activity in a scale during a performance test (Holl et al., 2010). Recording temperament during performance testing procedures may allow for temperament to be evaluated simultaneously with performance traits used in current selection programs.

Breed differences in behavior and temperament traits have been observed in pigs and are related to performance. Landrace pigs demonstrated a higher rate of tail-biting than Large

White pigs, and tail-biting was found to be negatively correlated with lean tissue growth and backfat levels (Breuer et al., 2005). Landrace sows savaged piglets at a higher rate than Duroc and crossbred sows, causing higher pre-wean death loss (Knap and Merks, 1987). However, studies have not reported breed differences in behaviors during handling and their relationship to performance traits.

Understanding the performance and temperament each breed contributes to its offspring is important for the success of a breeding program. The objectives of this study were to determine breed differences of temperament scores in pigs, and the phenotypic relationship between temperament scores and pig performance.

MATERIALS AND METHODS

Animals and Facilities

Boars and gilts from purebred Chester White (CW), Duroc (D), Landrace (L), and Yorkshire (Y) populations were made available by Ivey Spring Creek Genetics (Goldsboro, NC) in their facilities. Pedigree and performance data for all purebred animals included in this study were provided by the producer. Animals without correct pedigree information, correct identification, or a correct farrowing date, were removed from the data set and excluded from further analysis. A complete description of animals that received temperament scores (Table 2.1) are presented by breed and sex. All pigs scored for temperament had performance data, however not all pigs with performance data, received temperament scores.

Pigs were raised in a three-site production system and were finished in conventional, completely slatted, confinement buildings. Pigs were housed and evaluated on 3 different

finishing sites with a total of 13 individual buildings. Each building included a middle alleyway, and 18 pens on each side. The capacity of each building was 720 pigs with an average pen capacity of 20 pigs. The pens were all the same size, though not all pens were filled to capacity and several pens were left empty to facilitate performance testing. Each pen consisted of one fence line feeder, with four individual feeding spaces, and two bowl waters. Boars and gilts were separated by sex, placed randomly into pens throughout the barn, and were fed the same diet.

Data Collection

Pigs received three temperament scores at the time of a performance test. Pigs were weighed and ultrasounded at approximately 185 days of age, and all pigs performance tested received temperament scores. Pigs with obvious injuries or defects, indecipherable ear notches, and barrows were not scored for temperament or performance tested. Body weight was recorded at off-test, as well as backfat at the 10th rib and loin depth using longitudinal ultrasound; Aloka model 500V real-time ultrasound, Corometrics Medical Systems, Wallingford, CT (See et al., 2004). Backfat (BF) and loin depth (LD) were adjusted to 113.4 kg body weight using regression of the trait on off-test weight within each breed. Growth was expressed as number of days to reach 113.4 kg (DAYS) using methods recommend by NSIF (1997). Estimated percent fat-free lean (LEAN) was calculated using backfat, loin depth, and warm carcass weight as inputs (NPPC, 2000a). Carcass weight was calculated as 74% of live weight (NPPC, 2000a).

During the performance test, pigs were brought from their pen to an area that was designed specifically for performance testing pigs. Pigs were brought as a group, by one

member of the farm staff, from their pen to a holding pen at the end of the barn. Pigs were then moved from the holding pen to the adjacent loading pen. The scale was connected to an opening at the front of the loading pen. Two farm personnel separated pigs individually from the group in the loading pen and held the pig at the front of the scale while identification was read and recorded. The pig was then loaded into the scale. One temperament score was assessed during the loading process. Weight, BF, LD were measured and recorded by the ultrasound technician, and two temperament scores were recorded while the pig was in the scale. The pig was let out of the scale into an exit pen, and when all the pigs in the pen had been performance tested and scored, they were returned to an open pen in the building.

The scorer was located inside the pen next to the loading pen and scale. The scorer had full view of the loading pen, the area where pig identification was read, and the scale. All pigs were individually given three separate temperament scores, a load score (LS), scale score (SS), and vocal score (VS). Each score was determined by the scorer based on the response to the process of performance testing. The order in which each pig within a pen was loaded was also recorded. Scores were based on a 5 point scale and all pigs were scored by the same technician.

Load Score

Load score was assigned based on a pig's activity during the time in which it was loaded into the scale. It was adapted from a balking score in cattle during loading (Grandin, 1992) and a 5 point scale on which cattle (Grandin, 1994; Voisinet et al., 1997) and pigs (Holl et al., 2010) were scored based on their activity in a chute or scale. Scoring began when a pig was separated from its pen-mates in the loading pen, and continued up to the time

the pig entered the scale. Prior to entering the scale the pig was held in front of the scale and the pig's identification was recorded. The pig's response was included in the load score.

Pigs were scored on a 5 point scale based on the following responses that they may exhibit during loading:

- 1) Walked into the scale with minimal persuasion from farm personnel.
- 2) After identification was read, pig entered scale with multiple taps on the back.
- 3) Pig needed many taps on back or was physically pushed into the scale by farm personnel.
- 4) Made attempt(s) at escaping back into the pen at any time during the loading process. Pig may have been highly vocal during the loading process.
- 5) Attempted to jump out of pen or holding area, escaped back into pen, or if an electric prod was used to load the animal into the scale.

Scale Score

Scale score was developed from a 5 point chute or activity score (Grandin, 1994; Voisinet et al., 1997; Holl et al., 2010) used in cattle and pigs. Scale score was based on the actions of the pig for the duration of the time spent in the scale while performance data was recorded. The activity of the pig immediately after entry into the scale was not included in the SS as it may be a response to being loaded into the scale. After the ultrasound image was recorded and the pig was let out of the scale, and the SS was complete. Scale scores were based on the following responses to ultrasound measurement, and being in the scale:

- 1) No movement in the scale and ultrasound measurements were completed quickly.

- 2) Movements were slow. Moving of head from side to side.
- 3) Movements were moderate throughout. Movement was from front of scale to back of scale.
- 4) Movements were continuous and very fast. Pig slammed head against the scale door or tried to turn around inside scale.
- 5) Pig tried to jump out of the top of the scale or successfully turned around.

Vocal Score

The vocalization of the pig was not included in the SS because VS was scored separately. Vocal scores were scored simultaneously with SS, and were based on the vocal response the pig had to the ultrasound and being confined in the scale. The VS was assessed on the vocalization over the entire time the pig was in the scale. The VS was modified from the 5 point chute or activity score scale (Grandin, 1994; Voisinet et al., 1997; Holl et al., 2010) and a system used to quantify vocalization (Marchant et al., 2001). Vocal scores were assessed based on the following levels of vocal response to ultrasound measurement and being confined in a scale:

- 1) No vocalization during time in the scale.
- 2) A few random, soft vocalizations, or low grunts.
- 3) Constant soft vocalizations.
- 4) Infrequent loud vocalizations or high pitched squeals.
- 5) Constant excited or high pitched vocalizations.

Statistical Analysis

Breed and sex differences for LS, SS, and VS were estimated using the LOGISTIC procedure in SAS (SAS Inst. Inc., Cary, NC). Logistic regression allows for more accurate analysis of categorical data using a logit function (Taberner et al., 2008). The model for LS, SS, and VS included fixed effects of breed, sex, contemporary group (barn-farm-off-test date), and a covariate of off-test weight. The model for LS also included loading order as a fixed effect. Pairwise comparisons were done between breeds and sexes for each temperament score. Differences were reported as odds-ratios of the likelihood of an increase in temperament score by one breed compared to another breed or boars compared to gilts.

Differences in performance between breeds and sexes were tested by contrasting least squares means estimated using the GLM procedure in SAS. The statistical model for BF, LD, DAYS, and LEAN included fixed effects of breed, sex, contemporary group, and the appropriate temperament score. Weight was not included as a covariate because BF, LD, and DAYS were adjusted to a weight prior to analysis, and LEAN was calculated from unadjusted backfat and loin depth, and estimated carcass weight.

The relationships between temperament scores and performance were evaluated by contrasting the least square means of the performance traits at each category of LS, SS, and VS using the GLM procedure in SAS. After initial analysis it was concluded that VS was more accurately described as two categories, non-vocal and vocal. Vocal scores of 2, 3, 4, and 5 were represented at a low frequency (Table 2.2) compared to LS and SS, and did not differ ($P < 0.50$) for any performance traits. All data were re-analyzed with VS as a binary

trait. The linear relationship between all traits was calculated using Pearson correlation coefficients (van Erp-van der Kooij et al., 2002).

RESULTS AND DISCUSSION

The order in which a pig was loaded into the scale was significant as a fixed effect ($P < 0.001$) for LS. After initial analysis, it was determined that the first 13 pigs loaded had similar LS, and the fourteenth pig to the last pig of the pen were not significantly different. However, the two groups were significantly different ($P < 0.001$) in LS, and pigs that were loaded last were 1.65 ± 0.12 more likely to have an increase in LS than pigs that were loaded first. Loading order did not affect SS or VS, and was not found to affect the chute scores in cattle in previous studies (Voisinet et al., 1997).

Breed Differences

Breed differences (Table 2.3) for LS, SS, and VS are described as odds ratios with standard errors. The odds ratios are the likelihood of a breed increasing one temperament score unit compared to another breed. For VS, the odds ratio is the likelihood of pigs being vocal compared to non-vocal. Breed effects were significant ($P < 0.001$) for LS, SS, and VS. Landrace were more likely to have increased LS, SS, and VS than Y and D, and were more likely to show increased SS and VS than CW ($P < 0.01$). Chester White were more likely to have increased LS and SS than D or Y, and nearly twice as likely as D to be vocal ($P < 0.01$). Yorkshire had greater odds of increasing in all temperament scores compared to D ($P < 0.01$). Breed differences were evident for LS, SS and VS.

Breed differences for LS, SS and VS in pigs have not been previously reported. However, purebred lines have been compared in beef cattle, where similar temperament

evaluations have occurred. In a study evaluating chute scores, similar to SS in pigs, and flight speed as a measure of temperament in cattle, breed effects were significantly different. Limousin cattle had the highest average chute scores, while Angus had the lowest. Angus took the most time to exit the chute, indicating they experienced the least amount of stress while contained in a chute, while Limousin exited the fastest (Burrow et al., 2000). In another study of chute scores Bos indicus breeds were found to be significantly more temperamental compared to Bos taurus breeds (Voisinet et al., 1997).

Though breed differences for LS, SS, and VS haven't been quantified for pigs, a variety of temperament measures have revealed differences amongst pig breeds. Landrace pigs had the tendency of a higher rate of tail-biting than Large White pigs which affects the health of the pig, and its value at slaughter (Breuer et al., 2005). A study of sow aggressiveness revealed that Dutch Landrace were more aggressive toward their pigs than D sows, and corresponding crosses, indicated by an increased rate of savaging (Knaps and Merks, 1987). Cortisol levels were evaluated, as a measure of stress-handling ability, in pigs exposed to heat, mixing and stress of crowding. Meishan pig's cortisol levels were three times higher than L, and Y levels were twice as high as L, indicating L were the least capable of handling stress (Sutherland et al., 2006). Based on the results from previous studies, differences in breeds of livestock should be expected. Pigs have exhibited breed differences in temperament traits, and cattle have shown differences in temperament measures across breeds similar to those reported here in pigs.

Fixed effect of breed was significant ($P < 0.0001$) for BF, LD, DAYS, and LEAN. Breed differences were determined for performance traits from contrasts among least squares

means. Least squares means, and standard errors, for performance traits are listed along with least squares means for temperament scores in Table 2.4.

Breed differences for performance traits were estimated by comparing least squares means and the results of this study indicate differences in BF, LD, DAYS, and LEAN (Table 2.4). Chester White had the most BF, followed by D, Y, and L with the least amount of BF, and all breeds were significantly ($P < 0.01$) different; while the breeds that had the least amount of BF had the highest LEAN. Duroc and L had the largest LD and were not different from each other, and both had more muscle depth than Y ($P < 0.01$) which had greater LD than CW ($P < 0.01$). Durocs grew the fastest of all breeds, and CW grew faster ($P < 0.01$) than L and Y, which took the most DAYS.

Our results are similar to those reported in the National Pork Producer Council's terminal line evaluation. The evaluation included a variety of breeds and terminal lines, however only D and Y were represented in both the terminal line evaluation and the present study. Durocs had a higher thickness of backfat, and took 5 fewer days to reach 113.4 kgs than Y ($P < 0.05$). Durocs also had a lower carcass lean percent than Y, but were not significantly different ($P = 0.05$), and they did not differ in terms of loin muscle area (NPPC, 2000b). Loin shape is different between breeds, and the measures of loin muscle area may be better to describe the amount of muscle deposition.

Cassady et al. (2002) reported similar breed differences in a study designed to estimate heterosis and recombination effects in pigs. Durocs had the largest backfat depth, followed by CW, while Y and L had less, but similar measurements. Yorkshires had the largest loin muscle area, while L had the smallest area, and D and CW were between Y and

L, and were similar in their measurements. Backfat differences were similar to the results in this study, with the exception of CW being leaner than D. Miller et al. (1979) also reported that D pigs took 10 days less ($P < 0.01$) to reach 95 kg than Y pigs.

Sex Differences

Sex differences in temperament traits were also determined as odds ratios, and VS had a tendency to be different ($P \leq 0.15$) between boars and gilts. Gilts were 1.21 ± 0.11 more likely to become vocal while in the scale than boars. Sex was not significant in LS and SS. Although sex differences had not previously been quantified for LS, SS and VS in pigs, sex differences have been reported in cattle and other pig behavioral traits. The results of this study are similar to those found in a study on tail-biting, in which gilts were three times as likely ($P < 0.001$) to bite tails than barrows (Walker et al., 2006). In cattle heifers were more likely to be more active in a stressful situation. Steers had a significantly higher average exit time indicating they handled the stress of a chute better, than heifers (Burrow et al., 2000). Heifers also had a significantly higher average chute score, in several studies, than steers (Burrow et al., 2000; Voisinet et al., 1997) implying that steers were not as affected by the stress of a scale.

The fixed effect of sex was significant at a ($P = 0.0001$) for BF and ($P < 0.0001$) for LD, DAYS, and LEAN. Sex differences were determined for performance traits by contrasts among least squares means. Least squares means, and standard errors, for performance traits are listed along with least squares means for temperament scores in Table 2.4.

Gilts had more ($P < 0.01$) BF, larger LD, a higher LEAN, and took more DAYS than boars tested in this study. Sex differences were significant between gilts and barrows in the

terminal sire line evaluation (NPPC, 2000b), where barrows took fewer days to reach 113.4 kgs, had greater backfat depth, lower percent lean, and a smaller loin muscle area than gilts. Hale et al. (1967) also reported that barrows were significantly fatter and had a larger loin muscle area than gilts. The differences between sexes are widely accepted in the industry and are consistent with what was found in this study, with the exception of BF. However, sex difference estimates for BF in this study may be attributed to the inclusion of boars instead of barrows.

Phenotypic Relationships of Temperament and Performance

The relationship between temperament scores and performance traits were estimated by least squares means of performance at each category of the three temperament scores. The relationship of performance with LS is presented in (Table 2.5). As LS increased, DAYS increased ($P < 0.05$), while pigs scoring a 1 or 2 grew the fastest. As LS increased LD tended to increase and pigs that received a LS of 5 had the largest LD ($P < 0.05$). The relationship between performance and SS is presented in Table 2.6. Pigs that had a SS of 1 had the largest LD, and grew the fastest ($P < 0.05$). Pigs with the most BF had a SS of 1, and pigs with SS of 5 had the least BF ($P < 0.05$). Pigs that had a SS of 3, 4, or 5 had a higher LEAN than pigs that scored a 1 or 2. As SS increased, DAYS increased and BF decreased, while pigs with higher SS had a higher LEAN ($P < 0.05$). The relationship of performance with VS is presented in Table 2.7. Pigs that were non-vocal tended to have more BF, more LD, grew faster ($P < 0.05$), and had a lower LEAN than pigs that were vocal. In total these results indicate that as temperament scores increased, pigs tended to become leaner, have smaller LD, and grew slower, though pigs with the lowest scores did not always perform

better. Pigs with the highest or lowest temperament scores, many not always perform the best, and there may be an intermediate optimum for some temperament measures as they relate to performance.

Backtest in pigs was significantly associated with growth, showing calmer pigs grew faster. As backtest score increased pre-weaning ADG increased, and pigs with a backtest score of 2 gained 131 g/d more than pigs with a backtest score of 8 (Cassady, 2007).

Another study revealed that pigs with higher backtest scores had less muscle in their carcass and lower daily weight gain (van Erp-van der Kooij et al., 2003). Chute scores in cattle were also related to growth, and cattle with chute scores of 1 or 2 grew 0.19 kg/d faster ($P < 0.05$) than cattle of scores 3 or higher (Voisinet et al., 1997) similar to the results found in this study. Phenotypic relationships between pig temperament traits have also been reported. Pigs that had higher backtest scores were significantly more vocal than pigs with lower backtest scores (Hessing et al., 1994). Relationships between LS, SS, and VS with performance should be expected, as previous research has presented numerous examples of the relationship between temperament and performance in livestock.

Pearson correlation coefficients were used to quantify the phenotypic relationship between temperament scores and performance (Table 2.8). Load score was positively correlated ($P < 0.001$) with SS and VS, while SS was moderately and positively correlated with VS. This indicates that pigs expressing more excited temperament during loading should be expected to have increased activity and vocalization in the scale. In cattle, chute scores were positively correlated ($r = 0.09$) with exit velocity ($P < 0.10$) during an initial temperament test (Curley et al., 2006). Cattle that balked during loading were significantly

more excited in the chute than cattle that did not balk during loading (Grandin, 1992) indicating a favorable relationship between the two traits. In addition, chute scores have been reported to be moderately and negatively correlated ($r = -0.21$; $P < 0.01$) with flight speed of cattle; suggesting cattle that are more excited in the chute, leave the chute slower (Kadel et al., 2006).

Scale score was lowly and negatively correlated ($P < 0.001$) with BF and LD, but had low and positive correlations with DAYS, and LEAN. However, Holl et al. (2010) reported phenotypic correlations for scale activity with weight and backfat that were low and negative, and not significantly different than zero.

Vocal score was negatively correlated ($P < 0.01$) with BF, and positively correlated ($P < 0.001$) with SS, DAYS and LEAN. Pigs that were more active in the scale were more vocal. Pigs that were more responsive to the stress of the scale, and vocalized, tended have a decrease in BF and LD, but took more DAYS, and had an increased LEAN. Marchant et al. (2001) reported that vocalization in gilts was positively correlated with heart rate, which suggests that longer vocal calls are related to emotional distress.

In cattle flight speed had low, negative phenotypic correlations with carcass quality traits, ($r = -0.05$ and -0.07) meat water loss and Minolta scores. Chute scores similarly had low correlations with two different Minolta scores ($r = -0.06$ and -0.04) in cattle (Kadel et al., 2006). In another study Nkrumah et al. (2007) found that flight speed was found to be negatively correlated with carcass weight ($r_p = -0.25$) and yield grade ($r_p = -0.25$), but positively correlated with carcass loin muscle area ($r_p = 0.14$) in beef cattle.

CONCLUSION

The objective of breeding programs in the swine industry is to maximize profits, and in doing this, programs take advantage of the positive attributes of different breeds, to compensate for the weakness of others. To increase profits most breeding programs utilize differences in performance with little consideration to temperament of breeds and its relationship with performance.

Results from this study demonstrate that there are significant differences between breeds for temperament recorded during a performance test. The breeds evaluated are commonly used to create maternal and terminal lines, and their temperament should be considered when breeding decisions are made. Differences between sexes for vocalization were also found. Understanding differences in response to handling of boars and gilts is important in managing them in different production environments.

Pigs that exhibit less temperamental responses to stress have an unfavorable relationship with carcass composition but grew faster. Further research is needed to determine if improving temperament improves animal well-being and animal handling practices, and its net effect on production efficiency and profitability.

As the swine industry continues to work to improve animal well-being and handling procedures, potential for improvement of temperament through selection and design of breeding programs needs further investigation.

LITERATURE CITED

- Breuer, K., M.E.M. Sutcliffe, J.T. Mercer, K.A. Rance, N.E. O'Connell, I.A. Sneddon, and S. A. Edwards. 2005. Heritability of clinical tail-biting and its relation to performance traits. *Livestock Production Science* 93: 87-94.
- Burrow, H.M., and N.J. Corbet. 2000. Genetic and environmental factors affecting temperament of zebu and zebu-derived beef cattle grazed at pasture in the tropics. *Australian Journal of Experimental Agriculture* 51: 155-162.
- Cassady, J.P., L. D. Young and K. A. Leymaster. 2002. Heterosis and recombination effects on pig growth and carcass traits. *Journal of Animal Science* 80: 2286-2302.
- Cassady, J.P. 2007. Evidence of phenotypic relationships among behavioral characteristics of individual pigs and performance. *Journal of Animal Science* 85: 218-224.
- Curley, K.O., J.C. Paschal, T.H. Welsh, and R.D. Randel. 2006. Technical note: Exit velocity as a measure of cattle temperament is a repeatable and associated with serum concentration of cortisol in Brahman bulls. *Journal of Animal Science* 84: 3100-3103.
- Grandin, T. 1992. Behavioral agitation during handling of cattle is persistent over time. *Applied Animal Behaviour Science* 36: 1-9.
- Grandin, T. 1994. Solving livestock handling problems. *Vet. Med.* 89: 989-998.
- Hale, O.M., B.L. Southwell. 1967. Differences in Swine Performance and Carcass Characteristics because of Dietary Protein Level, Sex and Breed. *Journal of Animal Science* 26: 341-344.
- Hessing, M.J.C., W.G.P. Schouten, P.R. Wiepkema, M.J.M. Tielen. 1994. Implications of individual behavioral characteristics on performance in pigs. *Livestock Production Science* 40: 187-196.
- Holl, J.W., G.A. Rohrer, and T.M. Brown-Brandl. 2010. Estimates of genetic parameters among scale activity scores, growth, and fatness in pigs. *Journal of Animal Science* 88: 455-459.
- Kadel, M.J., D.J. Johnston, H.M. Burrow, H. Graser, and D.M. Ferguson. 2006. Genetics of flight time and other measures of temperament and their value as selection criteria for improving meat quality traits in tropically adapted breeds of beef cattle. *Australian Journal of Agricultural Research* 57: 1029-1035.
- Knap, P.W., and J.W.M. Merks. 1987. A Note on the Genetics of Aggressiveness of Primiparous Sows Toward their Piglets. *Livestock Production Science* 17: 161-167.

- Le Neindre, P., X. Boivin, and A. Boissy. 1996. Handling of extensively kept animals. *Appl. Anim. Behav. Sci.* 49: 73-81.
- Marchant, J.N., X. Whittaker, and D.M. Broom. 2001. Vocalisations of the adult female domestic pig during a standard human approach test and their relationships with behavioural and heart rate measures. *Applied Animal Behaviour Science* 72: 23-39.
- Miller, H.W., M.F. Cain, and H.D. Chapman. 1979. Performance of Purebred and Crossbred Pigs. *Journal of Animal Science* 49: 943-949.
- Nkrumah, J.D., D.H. Crews, J.A. Basarab, M.A. Price, E.K. Okine, Z. Wang, C. Li, and S.S. Moore. 2007. Genetic and Phenotypic relationships of feeding behavior and temperament with performance, feeding efficiency, ultrasound, and carcass merit of beef cattle. *Journal of Animal Science* 85: 2382-2390.
- NPPC. 2000a. Pork Composition and Quality Assessment Procedures. E. Berg, ed. Natl. Pork Prod. Council, Des Moines, IA.
- NPPC. 2000b. Genetic Evaluation, Terminal Line Program Results. R. Goodwin and S. Burroughs, ed. Natl. Pork Prod. Council, Des Moines, IA.
- NSIF. 1997. Guidelines for Uniform Swine Improvement Programs. Natl. Swine Improv. Fed., Jackson, TN.
- See, M.T., T.A. Armstrong, and W.C. Weldon. 2004. Effect of a ractopamine feeding program on growth performance and carcass composition in finishing pigs. *Journal of Animal Science* 82: 2474-2480.
- Sutherland, M.A., S.R. Niekamp, S.L. Rodriguez-Zas, and J.L. Salak-Johnson. 2006. Impacts of chronic stress and social status on various physiological and performance measures in pigs of different breeds. 2006. *Journal of Animal Science* 84: 588-596.
- Taberner, E., A. Medrano, A. Pena, T. Rigau, and J. Miro. 2008. Oestrus cycle characteristics and prediction of ovulation in Catalanian jennies. *Theriogenology* 70: 1489-1497.
- Van Erp-van der Kooij, E., A.H. Kuijpers, J.W. Schrama, F.J.C.M van Eerdenburg, W.G.P. Schouten, and M.J.M. Tielen. 2002. Can we predict behaviour in pigs? Searching for consistency in behaviour over time and across situations. *Applied Animal Behaviour Science* 75: 293-305.
- Van Erp-van der Kooij, E., A.H. Kuijpers, F.J.C.M. van Eerdengurg, and M.J.M. Tielen. 2003. Coping characteristics and performance in fattening pigs. *Livestock Production Science* 84: 31-38.

Voisinet, B.D., T. Grandin, J.D. Tatum, S.F. O'connor, and J.J. Struthers. 1997. Feedlot cattle with calm temperaments have higher average daily gains than cattle with excitable temperaments. *Journal of Animal Science* 75: 892-896.

Walker, P.K., G. Bilkei. 2006. Tail-biting in outdoor pig production. *The Veterinary Journal* 171: 367-369.

Table 2.1. Distribution of animals, according to breed, that received temperament scores

Breed	n	gilts	boars	sires	dams
Chester White	1,076	648	428	49	251
Duroc	1,832	986	846	71	343
Landrace	941	519	422	43	193
Yorkshire	925	524	401	45	203
Total	4,774	2,677	2,097	208	790

Table 2.2. Frequency^a of Temperament Scores by category

Trait	<u>Category</u>				
	1	2	3	4	5
Load Score	45.25 (2,160)	28.03 (1,338)	12.57 (600)	7.62 (364)	6.54 (312)
Scale Score	39.97 (1,908)	29.83 (1,424)	16.90 (807)	7.18 (343)	6.12 (292)
Vocal Score	89.48 (4,272)	3.46 (165)	2.37 (113)	2.81 (134)	1.89 (90)

^a Frequencies listed as percentage of pigs measured

(#) The number of pigs that received each score

Table 2.3. Breed differences¹ in temperament scores

Breed	<u>Load Score</u>		
	Chester White	Yorkshire	Duroc
Landrace	1.03 ± 0.09	1.30 ± 0.11 *	1.62 ± 0.12 **
Chester White		1.26 ± 0.10 *	1.58 ± 0.12 **
Yorkshire			1.25 ± 0.10 *
	<u>Scale Score</u>		
	Chester White	Yorkshire	Duroc
Landrace	1.77 ± 0.15 **	2.51 ± 0.22 **	3.31 ± 0.25 **
Chester White		1.42 ± 0.12 **	1.87 ± 0.14 **
Yorkshire			1.32 ± 0.10 **
	<u>Vocal Score</u>		
	Chester White	Yorkshire	Duroc
Landrace	2.37 ± 0.32 **	2.46 ± 0.35 **	3.94 ± 0.53 **
Chester White		1.04 ± 0.16	1.66 ± 0.25 **
Yorkshire			1.60 ± 0.25 *

¹Breed differences are characterized as odds ratios. The ratios are the likelihood of the breed in the left hand column compared to the breeds to the right increasing one temperament score unit.

*P < 0.01; ** P < 0.001

Table 2.4. Least Squares Means for temperament and performance traits by breed and sex

Trait ¹	<u>Breed</u>				P-value	<u>Sex</u>		P-value
	Chester White	Duroc	Landrace	Yorkshire		Gilts	Boars	
LS	2.15 ± 0.04 ^a	1.89 ± 0.03 ^b	2.15 ± 0.04 ^a	1.99 ± 0.04 ^c	< 0.001	2.07 ± 0.03 ^e	2.02 ± 0.03 ^e	0.352
SS	2.18 ± 0.04 ^a	1.80 ± 0.03 ^b	2.62 ± 0.04 ^c	2.05 ± 0.04 ^d	< 0.001	2.17 ± 0.03 ^e	2.16 ± 0.03 ^e	0.699
VS	1.10 ± 0.01 ^a	1.06 ± 0.01 ^b	1.20 ± 0.01 ^c	1.10 ± 0.01 ^a	< 0.001	1.13 ± 0.01 ^e	1.10 ± 0.01 ^e	0.157
BF	22.5 ± 0.1 ^a	20.6 ± 0.1 ^b	17.7 ± 0.1 ^c	19.6 ± 0.1 ^d	< 0.001	20.4 ± 0.1 ^e	19.7 ± 0.1 ^f	0.001
LD	58.8 ± 0.2 ^a	62.9 ± 0.2 ^b	63.2 ± 0.2 ^b	61.6 ± 0.2 ^c	< 0.001	62.9 ± 0.1 ^e	60.4 ± 0.2 ^f	< 0.001
DAYS	187.4 ± 0.4 ^a	186.5 ± 0.3 ^a	191.2 ± 0.4 ^b	191.5 ± 0.4 ^b	< 0.001	192.1 ± 0.3 ^e	186.2 ± 0.3 ^f	< 0.001
LEAN	48.30 ± 0.05 ^a	49.15 ± 0.04 ^b	50.42 ± 0.05 ^c	49.70 ± 0.06 ^d	< 0.001	49.53 ± 0.04 ^e	49.26 ± 0.04 ^f	< 0.001

^{a-d} Least squares means within a row with different superscripts indicate breed differences (P < 0.01)

^{e-f} Least squares means within a row with different superscripts indicate sex differences (P < 0.01)

¹ LS= load score, SS= scale score, VS= vocal score, BF= adjusted backfat (mm), LD= adjusted loin depth (mm), DAYS= days to 113.4 kg, LEAN= estimated percent fat-free lean (%)

Table 2.5. Least Squares Means of performance by Load Score

Trait	Load Score				
	1	2	3	4	5
Backfat ¹ (mm)	20.10 ± 0.10 ^a	20.02 ± 0.12 ^a	20.20 ± 0.18 ^a	19.98 ± 0.23 ^a	20.16 ± 0.24 ^a
Loin Depth ¹ (mm)	61.49 ± 0.15 ^a	61.39 ± 0.19 ^a	62.18 ± 0.28 ^b	61.22 ± 0.35 ^a	62.42 ± 0.38 ^b
Days to 113.4 kg	189.5 ± 0.3 ^a	188.7 ± 0.4 ^b	188.6 ± 0.6 ^{a,b}	189.5 ± 0.7 ^{a,b}	189.2 ± 0.8 ^{a,b}
Fat-free Lean (%)	49.39 ± 0.04 ^a	49.37 ± 0.05 ^a	49.35 ± 0.07 ^a	49.40 ± 0.09 ^a	49.44 ± 0.09 ^a

^{a-b} Least squares means within a row with different superscripts differ (P < 0.05)

¹ Adjusted to 113.4 kg through regression on off-test weight within each breed

Table 2.6. Least Squares Means of performance by Scale Score

Trait	Scale Score				
	1	2	3	4	5
Backfat ¹ (mm)	20.87 ± 0.10 ^a	19.66 ± 0.11 ^b	19.67 ± 0.15 ^b	19.46 ± 0.23 ^b	19.39 ± 0.25 ^b
Loin Depth ¹ (mm)	62.44 ± 0.16 ^a	60.96 ± 0.18 ^b	61.00 ± 0.24 ^b	61.37 ± 0.36 ^b	61.51 ± 0.40 ^b
Days to 113.4 kg	187.5 ± 0.3 ^a	189.5 ± 0.4 ^b	190.5 ± 0.5 ^{b,c}	191.2 ± 0.7 ^c	190.4 ± 0.8 ^{b,c}
Fat-free Lean (%)	49.09 ± 0.04 ^a	49.50 ± 0.04 ^b	49.55 ± 0.06 ^{b,c}	49.71 ± 0.09 ^c	49.65 ± 0.10 ^{b,c}

^{a-c} Least squares means within a row with different superscripts differ (P < 0.05)

¹ Adjusted to 113.4 kg through regression on off-test weight within each breed

Table 2.7. Least Squares Means of performance by Vocal Score

Trait	<u>Vocal Score</u>	
	1	2
Backfat ¹ (mm)	20.12 ± 0.07 ^a	19.83 ± 0.20 ^a
Loin Depth ¹ (mm)	61.64 ± 0.11 ^a	61.21 ± 0.31 ^a
Days to 113.4 kg	188.9 ± 0.2 ^a	190.4 ± 0.6 ^b
Fat-free Lean (%)	49.37 ± 0.03 ^a	49.48 ± 0.08 ^a

^{a-b} Least squares means within a row with different superscripts differ (P < 0.05)

¹ Adjusted to 113.4 kg through regression on off-test weight within each breed

Table 2.8. Phenotypic correlations of temperament scores and performance traits

Trait	Load Score	Scale Score	Vocal Score	Backfat ¹ (mm)	Loin Depth ¹ (mm)	Days to 113.4 kg (d)
Load Score						
Scale Score	0.13**					
Vocal Score	0.09**	0.32**				
Backfat ¹ (mm)	-0.01	-0.15**	-0.05*			
Loin Depth ¹ (mm)	0.02	-0.07**	-0.01	0.09**		
Days to 113.4 kg (d)	0.00	0.10**	0.05**	-0.12**	0.01	
Fat-Free Lean (%)	0.00	0.17**	0.08**	-0.83**	0.25**	0.46**

¹ Adjusted to 113.4 kg through regression on off-test weight within each breed

* Correlation significant at ($P < 0.01$)

**Correlation significant at ($P < 0.001$)

CHAPTER 3

ESTIMATES OF GENETIC PARAMETERS OF PIG TEMPERAMENT SCORES DURING PERFORMANCE TESTING AND PERFORMANCE TRAITS

ABSTRACT

The objective of this study was to estimate genetic parameters for temperament scores and performance traits recorded during a performance test. Chester White (CW), Duroc (D), Landrace (L), and Yorkshire (Y) boars and gilts were scored individually (n= 1,076, 1,832, 941, 925, respectively) for temperament; load score (LS), scale score (SS), and vocal score (VS). All temperament scores ranged from 1 (calm) to 5 (highly excited). Load score was recorded while pigs were loaded onto a scale. Pigs were simultaneously evaluated for SS and VS while on the scale and real-time ultrasound images recorded. Backfat depth adjusted to 113.4 kg (BF), loin depth adjusted to 113.4 kg (LD), days to 113.4 kg (DAYS), and estimated percent fat-free lean (LEAN) were recorded. After phenotypic analysis it was determined VS was best described by two categories, vocal and non-vocal, and was subsequently analyzed as a binary trait. Statistical models for LS, SS, and VS included fixed effects of sex and contemporary group (barn-farm-test date), covariate of off-test weight and random effect of animal, and were analyzed as categorical variables. Order in which pigs were loaded was included as a fixed effect for LS. Statistical models for performance traits included fixed effects of sex and contemporary group and random effect of animal, and were analyzed as continuous variables. Separate analyses were run for each breed. (Co)Variance components were estimated using THRGIBBS1F90 or GIBBSF90 with 150,000 cycles, 20,000 cycles burn in period, and every 20th sample was stored. Estimates of parameters of interest were obtained as statistics of their respective posterior distributions. Direct heritability estimates were (CW, D, L, Y): LS (0.05, 0.06, 0.06, 0.05), SS (0.22, 0.09, 0.09, 0.10), and VS (0.27, 0.24, 0.37, 0.21). Estimated heritability of LS was low regardless of

breed. Heritability estimates for SS, while higher than LS, were low with the exception of CW. Heritability estimates for VS were moderate. Direct genetic correlations between SS and VS obtained from a bivariate model were positive and moderate (0.30 to 0.75). Genetic correlations between temperament traits varied between breed, but were generally moderate and positive. The genetic correlations between LS, SS, and VS with performance traits ranged from -0.78 to 0.56, and varied amongst breeds. In general, current selection objectives for performance may affect temperament scores during a performance test. Direct selection for temperament scores collected during a performance test will also provide potential to alter pig behavior through selection.

Key words: heritability, genetic correlation, pigs, temperament, performance

INTRODUCTION

Currently genetic improvement programs are designed to select animals that produce multiple, large litters of fast and efficient growing pigs with high quality lean meat, and thus increase producer profits. Temperament is usually over-looked when selecting the best performing pigs. In cattle it has been hypothesized that intense selection for growth and leanness has resulted in increased problems in temperament during handling and restraint (Grandin et al., 1998). Quantifying the effect of selection for performance on temperament is important.

A number of methods have been developed to test temperament in pigs. Most temperament studies have been conducted with small pigs, due to ease of handling (Cassady, 2007), a few studies have measured temperament during a performance test of pigs (Holl et al., 2010), and several studies have been done with cattle (Burrow et al., 2000; Grandin, 1992). Recording temperament during a performance test allows for temperament data to be collected simultaneously with collection of weight and ultrasound data that are routinely used in swine selection programs. This minimizes the number of times that pigs are handled, because they are normally processed through a scale at this time.

Previous studies of the genetics of temperament in livestock suggest that a genetic component exists, and that temperament is genetically correlated with performance. Genetic parameters for activity while being confined in a scale have been reported in pigs (Holl et al., 2010) and cattle (Grandin, 1992). Flight speed, the speed in which an animal exits a scale or chute, has been demonstrated to be moderately heritable in cattle (Burrow et al., 2000), and pigs (Hansson et al., 2005).

The objectives of this study are to determine the heritability of three temperament traits that can be readily scored during a performance test, and to estimate genetic correlations between these temperament traits and the performance traits collected.

MATERIALS AND METHODS

Animals and Facilities

Boars and gilts from purebred Chester White (CW), Duroc (D), Landrace (L), and Yorkshire (Y) lines were made available by Ivey Spring Creek Genetics (Goldsboro, NC) in their facilities. Pedigree and performance data of all purebred animals included in this study were provided by the producer. Animals without correct pedigree information, correct identification, or a correct farrowing date, were removed from the data set. Animals (n= 4,774) with temperament scores (Table 3.1) and animals (n= 53,041) with performance data (Table 3.2) are listed by breed and sex. All pigs that were scored for temperament had performance data, however not all pigs with performance data, received temperament scores.

Pigs were raised in a three-site production system and were finished in conventional, completely slatted, confinement buildings. Pigs were housed on 3 different finishing sites with 13 individual buildings. Each building included a middle alleyway, and 18 pens on each side. The capacity of each building was 720 pigs with pen capacity of 20 pigs; though not all pens were filled to capacity and several left empty. Each pen consisted of one fence line feeder, with four individual feeding spaces, and two bowl waters. Boars and gilts were separated by sex, placed randomly into pens throughout the barn, and were fed the same diet.

Data Collection

Pigs received three temperament scores at the time of a performance test. Pigs were weighed and ultrasounded at approximately 185 days of age, and all pigs performance tested received temperament scores. Pigs with obvious injuries or defects, indecipherable ear notches, and barrows were not scored for temperament or performance tested. Body weight was recorded at off-test, as well as backfat at the 10th rib and loin depth using longitudinal ultrasound; Aloka model 500V real-time ultrasound, Corometrics Medical Systems, Wallingford, CT (See et al., 2004). Backfat (BF) and loin depth (LD) were adjusted to 113.4 kg body weight using regression of the trait on off-test weight within each breed. Growth was expressed as number of days to reach 113.4 kg (DAYS) using methods recommend by NSIF (1997). Estimated percent fat-free lean (LEAN) was calculated using backfat, loin depth, and warm carcass weight as inputs (NPPC, 2000a). Carcass weight was calculated as 74% of live weight (NPPC, 2000a).

During a performance test, pigs were brought from their pen to an area that was designed specifically for performance testing pigs. Pigs were brought as a group, by one member of the farm staff, from their pen to a holding pen at the end of the barn. Pigs were then moved from the holding pen to the adjacent loading pen. The scale was connected to an opening at the front of the loading pen. Two farm personnel separated pigs individually from the group in the loading pen and held the pig at the front of the scale while identification was read and recorded. The pig was then loaded into the scale. One temperament score was assessed during the loading process. Weight, BF, LD were measured and recorded by the ultrasound technician, and two temperament scores were recorded while the pig was in the

scale. The pig was let out of the scale into an exit pen, and when all the pigs in the pen had been performance tested and scored, they were returned to an open pen in the building.

The scorer was located inside the pen next to the loading pen and scale. The scorer had full view of the loading pen, the area where pig identification was read, and the scale. All pigs were individually given three separate temperament scores, a load score (LS), scale score (SS), and vocal score (VS). Each score was determined by the scorer based on response to the process of confinement on the scale and ultrasound measurement. Order in which each pig within a pen was loaded was also recorded. Scores were based on a 5 point scale and all pigs were scored by the same technician.

Load Score

Load score was assigned based on a pig's activity during the time in which it was loaded into the scale. It was adapted from a balking score in cattle during loading (Grandin, 1992) and a 5 point scale on which cattle (Grandin, 1994; Voisinet et al., 1997) and pigs (Holl et al., 2010) were scored based on their activity in a chute or scale. Scoring began when the pig was separated from its pen-mates in the loading pen, and continued up to the time a pig entered the scale. Prior to entering the scale the pig was held in front of the scale and the pig's identification was recorded. The pig's response was included in the load score.

Pigs were scored on a 5 point scale based on the following responses that they may exhibit during loading:

- 1) Walked into the scale with minimal persuasion from farm personnel.
- 2) After identification was read, pig entered scale with multiple taps on the back.

- 3) Pig needed many taps on back or was physically pushed into the scale by farm personnel.
- 4) Made attempt(s) at escaping back into the pen at any time during the loading process. Pig may have been highly vocal during the loading process.
- 5) Attempted to jump out of pen or holding area, escaped back into pen, or if an electric prod was used to load the animal into the scale.

Scale Score

Scale score was developed from a 5 point chute or activity score (Grandin, 1994; Voisinet et al., 1997; Holl et al., 2010) used in cattle and pigs. Scale score was based on the actions of the pig for the duration of the time spent in the scale while performance data was recorded. The activity of the pig immediately after entry into the scale was not included in the SS as it may be a response to being loaded into the scale. After the ultrasound image was recorded and the pig was let out of the scale, and the SS was complete. Scale scores were based on the following responses to ultrasound measurement, and being in the scale:

- 1) No movement in the scale and ultrasound measurements were completed quickly.
- 2) Movements were slow. Moving of head from side to side.
- 3) Movements were moderate throughout. Movement was from front of scale to back of scale.
- 4) Movements were continuous and very fast. Pig slammed head against the scale door or tried to turn around inside scale.
- 5) Pig tried to jump out of the top of the scale or successfully turned around.

Vocal Score

The vocalization of the pig was not included in the SS because VS was scored separately. Vocal scores were scored simultaneously with SS, and were based on the vocal response the pig had to the ultrasound and being confined in the scale. The VS was assessed on the average vocalization over the entire time the pig was in the scale. The VS was modified from the 5 point chute or activity score scale (Grandin, 1994; Voisinet et al., 1997; Holl et al., 2010) and a system used to quantify vocalization (Marchant et al., 2001). Vocal scores were assessed based on the following levels of vocal response to ultrasound measurement and being confined in a scale:

- 1) No vocalization during time in the scale.
- 2) A few random, soft vocalizations, or low grunts.
- 3) Constant soft vocalizations.
- 4) Infrequent loud vocalizations or high pitched squeals.
- 5) Constant excited or high pitched vocalizations.

Statistical Analysis

Phenotypic analysis was done using the LOGISTIC and GLM procedures in SAS (SAS Inst. Inc., Cary, NC) to determine the appropriate statistical models for further genetic analysis. After phenotypic analysis was complete, it was concluded that VS was best described as two categories, non-vocal and vocal. Backfat, LD, DAYS, and LEAN were not different ($P < 0.50$) for VS categories 2, 3, 4, and 5, which had lower frequencies (Table 3.3) than LS and SS. Phenotypic analysis was repeated, and genetic analysis was completed with VS analyzed as a binary trait.

Due to the absence of genetic ties or common ancestors between breeds, analyses were done separately for the CW, D, L, and Y breeds. Data for animals that received temperament scores (n= 4,774) and animals with performance data (n= 53,041) were used for analyses. (Co) Variance estimates for temperament traits (LS, SS, and VS) were obtained using data only from animals with temperament scores (Table 3.1). Statistical models for LS, SS, and VS included fixed effects of sex and contemporary group (barn-farm-test date), covariate of off-test weight and animal as a random effect. Order in which pigs were loaded had an effect on LS and was included as a fixed effect for LS. (Co)Variance component estimates for LS, SS, and VS were estimated using two-trait models.

A separate analysis of (co)variance between performance traits was conducted with a four-trait (BF-LD-DAYS-LEAN) animal model. The model for performance traits included fixed effects of sex and contemporary group and a random animal effect. Estimation of genetic parameters for performance traits utilized all available performance data and pedigree information (Table 3.2).

Estimates of covariance between temperament scores and performance traits were calculated from animals that had temperament scores and performance data (Table 3.1). This resulted in more conservative estimates of genetic correlations between temperament traits and performance traits (BF, LD, DAYS, and LEAN). The models for temperament scores and performance traits were the same as previously stated, and covariance components were estimated using a two trait model.

It has been found that heritability estimates for categorical traits with an underlying quantitative genetic component, are greater using a threshold linear model than a continuous

linear model (Gianola, 1979). Analyses calculating (co)variances components of LS, SS, and VS, and the covariance between temperament and performance was completed using THRGIBBS1F90 (Tsurutra and Misztal, 2006) a simplified version of THRGIBBSF90 (Misztal et al., 2002). This software program allows for any combination of categorical and continuous traits to be analyzed together (Lee et al., 2002). Estimates of (co)variance for performance traits were determined using GIBBSF90 (Iwaisaki et al., 2005). Estimates of parameters of interest were obtained as statistics of their respective posterior distributions calculated using POSTGIBBSF90 (Misztal et al., 2002).

All analyses were run with 150,000 single chain cycles with a burn-in period of 20,000 cycles. Every 20th sample was stored leaving 6,500 stored samples to calculate posterior means, standard deviations, and highest posterior density. Results were used to calculate direct heritabilities and direct genetic correlations for all traits. Starting values for (co)variance components were obtained as phenotypic (co)variances from the phenotypic analysis.

RESULTS AND DISCUSSION

Heritability of Temperament

Variance components and estimates of heritability for temperament scores and performance traits are listed by breed, CW (Table 3.4), D (Table 3.5), L (Table 3.6), and Y (Table 3.7). Heritability estimates for LS were low for all breeds, and estimates for SS were low for all breeds except for CW, which was moderately heritable. Estimates of heritability for VS were moderate for all breeds. These results indicate that improvement in temperament can be made through direct selection for these scores. Estimates of heritability

for LS and SS were low due to low estimates of genetic variance and high environmental variance.

Genetic parameters for LS and VS were not found in literature but, heritabilities of scale activity in pigs and chute scores in cattle have been reported. Scale activity score during a performance test in pigs was found to be moderately heritable (0.23) using a five trait linear model (Holl et al., 2010). The estimate is higher than estimates found in this study for D, Y and L, but is similar to our estimate for CW. Holl et al. (2010) used data collected on crossbred animals, while this study used purebred animals. This may have resulted in lower estimates of additive variance, and may explain the lower estimates of heritability.

Heritability of chute score in cattle has been reported as 0.10 (Hearnshaw and Morris, 1984), which is similar to estimates of LS and SS found in this study, to moderately heritable (0.30) in a study by Burrow (2000). Flight speed, the speed which an animal exits the chute or scale, was found to be moderately heritable with estimates of 0.35 (Burrow et al., 2000) and 0.44 (Burrow, 2001) in cattle, and 0.20 (Hannson et al., 2005) in pigs.

Heritability has also been estimated for other temperament traits in livestock. Savaging of piglets by sows ranged from lowly (0.12) to moderately (0.25) heritable (Knap and Merks, 1987). Tailbiting has been reported as lowly heritable (0.05) in Landrace and Large White pigs (Breuer et al., 2005). Heritability estimates for pig feeding behaviors ranged from low (0.06) to moderately (0.34) heritable (Hall et al., 1999).

Heritability of Performance

Heritability estimates for performance traits were consistent across breeds. Backfat was moderately heritable for all breeds, but slightly higher in L. Estimates of heritability for

BF in all breeds were within the range, 0.23 (Siers and Thomson, 1972) to 0.54 (Lo et al., 1992) established in other studies. Estimates for LD were moderate for white line breeds, and high for D. In a study done by Siers and Thomson (1972) the heritability for LD ranged from 0.56 to 0.63, while an estimate of 0.13 was also found by van Wijk et al. (2005). Heritability estimates for DAYS were high in all breeds, and LEAN heritability estimates were high for D and Y, but moderate for CW and L. Average daily gain, a measure of growth had a heritability of 0.46 (Lo et al., 1992) while days to 113.4 kg was estimated at 0.57 in an evaluation of terminal sires (NPPC, 2000b) and is similar to the results of this study. Percent lean has been previously reported with heritability estimates of 0.43 (van Wijk et al., 2005), 0.48 (Stewart and Schinkel, 1989) and 0.52 (NPPC, 2000b).

Genetic Correlations between Temperament and Performance

Covariance and genetic correlation estimates between temperament scores and performance traits are listed in Table 3.8 (CW), Table 3.9 (D), Table 3.10 (L), and Table 3.11 (Y). Load score had a low, negative genetic correlation with SS in CW and Y, indicating that pigs with lower load scores are more active when in the scale. However, the genetic correlation between LS and SS was positive and moderate for D, and high for L. Load score had a positive genetic correlation with VS for all breeds, suggesting pigs with higher LS are more vocal. Magnitude of the genetic correlation between LS and VS differed among breeds and was low in D and Y, moderate in CW and high in L. Moderate to high genetic correlations were observed for all breeds between SS and VS indicating that as activity in the scale increased vocalization occurred. In general temperament scores were positively

correlated indicating that an increase in one temperament score would result in an increase in the other temperament scores.

Genetic relationships between similar sets of temperament scores to those measured in this study have not been previously reported. However, genetic relationships between different behaviors have been documented. A study in persistence of pig temperament showed that pigs that were aggressive early in life tended to be more aggressive later in life and during other temperament measures (D'Eath, 2002). Flight speed in cattle was negatively correlated with chute scores ($r = -0.21$ to -0.23) meaning cattle that were calmer in the chute left the chute slower (Kadel et al., 2006). Aggression score has been reported to be genetically correlated with the number of escape attempts in cattle where high aggression toward a handler was highly and positively correlated ($r = 0.84$) with escape attempts (Phocas et al., 2006). Although genetic correlations were not estimated, cattle that had more excited loading behavior were more likely to be active in a chute, and this behavior was found to be persistent during scoring repetition (Grandin, 1992). These previous studies also suggest that as multiple measurements of temperament in livestock are recorded, animals that are temperamental for one trait will be temperamental for another, which corresponds with the results of this study.

Genetic correlations between temperament scores and performance traits varied among breeds. Some were positively correlated, others were negatively correlated, and some were not related. Load score had a positive genetic correlation with BF, indicating leaner pigs had lower LS, except in D which had a negative genetic correlation. Genetic correlations between SS, VS and BF were negative for the Y, D, and L breeds indicating

fatter pigs had lower SS and VS. Landrace though, had low and positive genetic correlations between BF and both SS and VS.

Positive genetic correlations between LD and LS, SS, and VS in CW suggest pigs with increased muscle depth will have increased temperament scores. However, estimates of the genetic correlation between LS and LD for D, L, and Y were near zero. Estimates of genetic correlations between LD and SS were low and negative for D and Y and moderate for L, indicating pigs with larger LD had lower activity in the scale. Similarly, LD in D and Y had high and negative genetic correlations with VS indicating pigs with more muscle depth were less vocal. The genetic correlation between VS and LD in L was near zero. With the exception of CW the genetic correlations would indicate increased LD results in lower temperament scores suggested heavier muscled pigs may have a decrease in activity during loading and in the scale, and decreased vocalization. However, it should be considered that LD is not the best indicator of overall muscling and the shape of the loin differs between breeds.

Genetic correlations were near zero between SS and DAYS for D, between VS and DAYS for L, and between LS and DAYS for CW. Genetic correlations between LS and DAYS were positive for D and Y, but negative in L. Chester White had a moderate, positive genetic correlation between SS and DAYS. However, in L and Y the genetic correlation between SS and days was negative. Estimates of genetic correlations between VS and DAYS were consistently low but were positive for CW and Y and negative for D. The genetic relationships between temperament and DAYS were inconsistent between breeds and the three temperament scores.

Estimates of genetic correlations between LS, SS, VS and LEAN for L ranged from low to moderate, and were all negative suggesting increased leanness in L results in decreased temperament scores. However, in Y higher LEAN would result in increased LS, SS, and VS. Moderate and positive SS and LEAN in CW and D. Estimates of genetic correlations were moderate and positive between VS and LEAN in CW but negative in D. Likewise genetic correlations between LS and LEAN were positive in D and negative in CW. Estimates of genetic correlations between LS and SS with the measured performance traits were inconsistent across breeds.

No genetic correlations between LS and VS with performance were found in the literature. However, temperament has been shown to be genetically correlated with performance in livestock. Flight speed in pigs had a positive correlation with average daily gain ($r_g = 0.21$) and backfat ($r_g = 0.26$), suggesting pigs that grew slower and leaner, left the scale faster (Hannson et al., 2005). These results are similar to the relationships found in this study for most breeds. Scale activity score in pigs had a negative genetic correlation with weight ($r_g = -0.38$) and three different measurements of backfat that ranged from -0.11 to -0.16 (Holl et al., 2010). Again the results of this study tended to be similar indicating that pigs that grow faster, and are fatter, are less active in the scale. Flight speeds and chute scores in cattle were found to have a favorable genetic correlation with meat tenderness (Kadel et al., 2006). In general, our results and those reported in the literature would suggest that selection for improved temperament would result in improved growth and decreased leanness.

Genetic Correlations between Performance Traits

The genetic correlation between BF and LD was negative and favorable for CW and D, but was positive for L and Y, though estimates were near zero. Estimates of the genetic correlation between BF and DAYS were all near zero or low. All genetic correlations between BF and LEAN were near zero; however, Y had a slightly positive, unfavorable correlation. Loin depth and DAYS were positively and unfavorably correlated for CW, D and L, but were negative and favorably correlated for Y. Loin depth was positive and favorably correlated with LEAN for D and L, but was near zero for CW and Y. All breeds had positive and unfavorable correlations between DAYS and LEAN.

The terminal sire evaluation conducted by the National Pork Producers Council (2000b) found backfat at the tenth rib had a negative, favorable genetic correlation ($r_g = -0.61$) with loin muscle area and a genetic correlation ($r_g = -0.05$) that was near zero with DAYS. The genetic correlation between DAYS and loin muscle area was near zero ($r_g = 0.05$) but unfavorably correlated. Reports of correlations between BF and LEAN were much lower in this study than what had been reported ($r = -0.87$) and the correlation between LEAN and loin muscle area was lower as well ($r_g = 0.65$), with the exception of D (Stewart and Schinkel, 1989). The estimate between age to 103.6 kg and ultrasound backfat was low ($r_g = -0.13$) in another study (Lo et al., 1992). Estimates of genetic correlations from this study were not consistent with those found in literature; however, LD was measured instead of loin muscle area, and those may be different traits.

CONCLUSION

The need for research involving temperament continues to increase as the swine industry works to improve animal well-being and handling procedures. Understanding the genetic relationship of temperament and performance will be essential in designing future selection programs. Based on these results, direct selection for improved temperament scores collected during a performance test provide potential to alter pig behavior. The effect of current selection programs for improved performance on temperament was inconsistent, and varied between breeds and temperament scores. However generally, selection for leaner pigs resulted in pigs that were more active during loading and were more active and vocal in the scale. Pigs that were selected for increased muscled depth were calmer during loading and in the scale. As pigs grew faster they tended to be more active in the scale, but easier to load and less vocal. Estimates involving LS may be inconsistent because the majority of variance was environmental.

Current selection criteria for improvement in performance may affect temperament differently for different temperament measures and in different breeds. Further research also needs to be conducted to determine how temperament measures relate to pig behavior in other production situations and during handling. The effects of selection for temperament change on finishing and reproductive performance, survivability, meat quality, and handling ease needs to be quantified before inclusion of temperament in selection procedures is considered.

LITERATURE CITED

- Breuer, K., M.E.M. Sutcliffe, J.T. Mercer, K.A. Rance, N.E. O'Connell, I.A. Sneddon, and S. A. Edwards. 2005. Heritability of clinical tail-biting and its relation to performance traits. *Livestock Production Science* 93: 87-94.
- Burrow, H.M., and N.J. Corbet. 2000. Genetic and environmental factors affecting temperament of zebu and zebu-derived beef cattle grazed at pasture in the tropics. *Australian Journal of Experimental Agriculture* 51: 155-162.
- Burrow, H.M. 2001. Variances and covariance between productive and adaptive traits and temperament in a composite breed of tropical beef cattle. *Livestock Production Science* 70: 213-233.
- Cassady, J.P. 2007. Evidence of phenotypic relationships among behavioral characteristics of individual pigs and performance. *Journal of Animal Science* 85: 218-224.
- D'Eath, R.B. Individual aggressiveness measured in a resident-intruder predicts the persistence of aggressive behaviour and weight gain of young pigs after mixing. 2002. *Applied Animal Behaviour Science* 77: 267-283.
- Gianola, D. 1979. Heritability of polychotomous characters. *Genetics* 93: 1051-1055.
- Grandin, T. 1992. Behavioral agitation during handling of cattle is persistent over time. *Applied Animal Behaviour Science* 36: 1-9.
- Grandin, T. 1994. Solving livestock handling problems. *Vet. Med.* 89: 989-998.
- Grandin, T., and M. J. Deesing. 1998. Genetics and behavior during handling, restraint, and herding. In: Grandin, T. (ed.), *genetics and the behavior of domestic animals*. Academic Press, San Diego, USA, pp. 113-144.
- Hall, A.D., W.G. Hill, P.R. Bampton, and A.J. Webb. 1999. Genetic and phenotypic parameter estimates for feeding pattern and performance test traits in pigs. *Journal of Fundamental and Applied Research*. 68: 43-48.
- Hansson, A.C., R.E. Crump, H.U. Graser, and R. Sokolinski. 2005. Relationships among temperament and production traits of pigs. *Advancement of Animal Breeding and Genetics* 25: 141-148.
- Hearnshaw, H., and C.A. Morris. 1984. Genetic and Environmental Effects on a Temperament Score in Beef Cattle. *Australian Journal of Agricultural Research* 35: 723-733.

- Holl, J.W., G.A. Rohrer, and T.M. Brown-Brandl. 2010. Estimates of genetic parameters among scale activity scores, growth, and fatness in pigs. *Journal of Animal Science* 88: 455-459.
- Iwaisaki, H., S. Tsuruta, I. Misztal and J. K. Bertrand. 2005. Genetic parameters estimated with multitrait and linear spline-random regression models using Gelbvieh early growth data. *Journal of Animal Science* 83: 757-763.
- Kadel, M.J., D.J. Johnston, H.M. Burrow, H. Graser, and D.M. Ferguson. 2006. Genetics of flight time and other measures of temperament and their value as selection criteria for improving meat quality traits in tropically adapted breeds of beef cattle. *Australian Journal of Agricultural Research* 57: 1029-1035.
- Knap, P.W., and J.W.M. Merks. 1987. A Note on the Genetics of Aggressiveness of Primiparous Sows Toward their Piglets. *Livestock Production Science* 17: 161-167.
- Lee, D., I. Misztal, J.K. Bertrand, and R. Rekaya. 2002. National evaluation of calving ease, gestation length and birth weight by linear and threshold model methodologies. *Journal of Applied Genetics* 43: 209-216.
- Lo, L.L., D.G. McLaren, F.K. McKeith, R.L. Fernando, and J. Novakofski. 1992. Genetic analyses of growth, real-time ultrasound, carcass, and pork quality traits in Duroc and Landrace pigs II: Heritabilities and correlations. *Journal of Animal Science* 70: 2373-2386.
- Marchant, J.N., X. Whittaker, and D.M. Broom. 2001. Vocalisations of the adult female domestic pig during a standard human approach test and their relationships with behavioural and heart rate measures. *Applied Animal Behaviour Science* 72: 23-39.
- Misztal, I., S. Tsuruta, T. Strabel, B. Auvray, T. Druet, and D. H. Lee. 2002. BLUPF90 and related programs (BGF90). Communications No. 28-07 in Proc. 7th World Cong. Genet. Appl. Livestock Production., Montpellier, France.
- NPPC. 2000a. Pork Composition and Quality Assessment Procedures. E. Berg, ed. Natl. Pork Prod. Council, Des Moines, IA.
- NPPC. 2000b. Genetic Evaluation, Terminal Line Program Results. R. Goodwin and S. Burroughs, ed. Natl. Pork Prod. Council, Des Moines, IA.
- NSIF. 1997. Guidelines for Uniform Swine Improvement Programs. Natl. Swine Improv. Fed., Jackson, TN.

- Phocas, F., X. Boivin, J. Sapa, G. Trillat, A. Boissy, and P. Le Neindre. 2006. Genetic correlations between temperament and breeding traits in Limousin heifers. *Animal Science* 82: 805-811.
- See, M.T., T.A. Armstrong, and W.C. Weldon. 2004. Effect of a ractopamine feeding program on growth performance and carcass composition in finishing pigs. *Journal of Animal Science* 82: 2474-2480.
- Siers, D.G., and G.M. Thomson. 1972. Heritabilities and Genetic Correlations of Carcass and Growth Traits in Swine. *Journal of Animal Science* 35: 311-316.
- Stewart, T.S., and A.P. Schinkel. 1989. Genetic parameters for swine growth and carcass traits. In: Young, L.D. (ed.) *Genetics of Swine*. USDA-ARS, Clay Center, Nebraska, pp. 77-79.
- Tsuruta, S., and I. Misztal. 2006. THRGIBBS1F90 for estimation of variance components with threshold and linear models. Communication No. 27-31 in Proc 8th World Cong. Genet. Appl. Livestock Production, Belo Horizonte, Minas Gerais, Brazil.
- van Wijk, H.J., D.J.G. Arts, J.O. Matthews, M. Webster, B.J. Ducro, and E.F. Knol. 2005. Genetic parameters for carcass composition and pork quality estimated in a commercial production chain. *Journal of Animal Science* 83: 324-333.
- Voisinet, B.D., T. Grandin, J.D. Tatum, S.F. O'connor, and J.J. Struthers. 1997. Feedlot cattle with calm temperaments have higher average daily gains than cattle with excitable temperaments. *Journal of Animal Science* 75: 892-896.

Table 3.1. Distribution of animals, according to breed, that received temperament scores

Breed	n	gilts	boars	sires	dams
Chester White	1,076	648	428	49	251
Duroc	1,832	986	846	71	343
Landrace	941	519	422	43	193
Yorkshire	925	524	401	45	203
Total	4,774	2,677	2,097	208	790

Table 3.2. Distribution of animals, according to breed, with performance data collected

Breed	n	gilts	boars	sires	dams
Chester White	14,119	9,294	4,825	227	1,539
Duroc	21,049	9,328	11,721	329	1,753
Landrace	7,884	3,805	4,079	191	729
Yorkshire	9,989	4,803	5,186	218	815
Total	53,041	27,230	25,811	965	4,836

Table 3.3. Frequency^a of Temperament Scores by category

Trait	<u>Category</u>				
	1	2	3	4	5
Load Score	45.25 (2,160)	28.03 (1,338)	12.57 (600)	7.62 (364)	6.54 (312)
Scale Score	39.97 (1,908)	29.83 (1,424)	16.90 (807)	7.18 (343)	6.12 (292)
Vocal Score	89.48 (4,272)	3.46 (165)	2.37 (113)	2.81 (134)	1.89 (90)

^a Frequencies listed as percentage of pigs measured

(#) The number of pigs that received each score

Table 3.4. Estimates of variance components^a and heritabilities for temperament scores: Load Score (LS), Scale Score (SS), Vocal Score (VS), and performance traits: Backfat (BF), Loin Depth (LD), Days to 113.4 kg (DAYS), and Percent Fat-Free Lean (LEAN) for Chester White

Trait	σ_a^2				h_a^2	σ_e^2			
	Mean	S.D.	HPD ^b			Mean	S.D.	HPD ^b	
LS	0.10	0.09	0.01 to	0.28	0.05	1.90	0.25	1.57 to	2.52
SS	0.39	0.15	0.11 to	0.66	0.22	1.37	0.17	1.04 to	1.71
VS	0.37	0.25	0.03 to	0.83	0.27	1.02	0.06	0.90 to	1.14
BF ¹ (mm)	0.25	0.03	0.21 to	0.31	0.34	0.49	0.02	0.46 to	0.52
LD ¹ (mm)	0.01	0.01	0.00 to	0.01	0.42	0.01	0.01	0.00 to	0.01
DAYS (d)	21.76	1.28	19.36 to	24.33	0.53	19.61	0.78	18.10 to	21.18
LEAN (%)	0.18	0.02	0.15 to	0.21	0.43	0.23	0.01	0.21 to	0.25

¹ Adjusted to 113.4 kg through regression of backfat on off-test weight within breed

^a σ_a^2 = direct additive genetic variance; σ_e^2 = residual variance; h_a^2 = direct heritability

^b Highest posterior density (95%) interval

Table 3.5. Variance Estimates of variance components^a and heritabilities for temperament scores: Load Score (LS), Scale Score (SS), Vocal Score (VS), and performance traits: Backfat (BF), Loin Depth (LD), Days to 113.4 kg (DAYS), and Percent Fat-Free Lean (LEAN) for Duroc

Trait	σ_a^2			h_a^2	σ_e^2		
	Mean	S.D.	HPD ^b		Mean	S.D.	HPD ^b
LS	0.11	0.06	0.00 to 0.23	0.06	1.76	0.16	1.55 to 2.17
SS	0.14	0.06	0.03 to 0.27	0.09	1.51	0.13	1.27 to 1.77
VS	0.32	0.20	0.05 to 0.70	0.24	1.01	0.05	0.92 to 1.10
BF ¹ (mm)	0.34	0.02	0.30 to 0.39	0.38	0.56	0.02	0.53 to 0.59
LD ¹ (mm)	0.01	0.01	0.01 to 0.02	0.62	0.01	0.01	0.01 to 0.02
DAYS (d)	15.49	0.90	13.74 to 17.25	0.51	14.73	0.53	13.64 to 15.70
LEAN (%)	0.26	0.01	0.24 to 0.29	0.50	0.26	0.01	0.25 to 0.28

¹ Adjusted to 113.4 kg through regression of backfat on off-test weight within breed

^a σ_a^2 = direct additive genetic variance; σ_e^2 = residual variance; h_a^2 = direct heritability

^b Highest posterior density (95%) interval

Table 3.6. Estimates of variance components^a and heritabilities for temperament scores: Load Score (LS), Scale Score (SS), Vocal Score (VS), and performance traits: Backfat (BF), Loin Depth (LD), Days to 113.4 kg (DAYS), and Percent Fat-Free Lean (LEAN) for Landrace

Trait	σ_a^2			h_a^2	σ_e^2		
	Mean	S.D.	HPD ^b		Mean	S.D.	HPD ^b
LS	0.16	0.15	0.00 to 0.48	0.06	2.54	0.37	2.11 to 3.55
SS	0.15	0.86	0.00 to 0.29	0.09	1.64	0.57	1.28 to 2.12
VS	0.61	0.63	0.52 to 1.23	0.37	1.02	0.10	0.09 to 1.15
BF ¹ (mm)	0.18	0.02	0.15 to 0.21	0.47	0.20	0.21	0.19 to 0.22
LD ¹ (mm)	0.01	0.01	0.00 to 0.01	0.40	0.01	0.01	0.01 to 0.01
DAYS (d)	25.04	2.51	20.32 to 30.28	0.51	23.74	1.48	20.76 to 26.61
LEAN (%)	0.13	0.02	0.09 to 0.17	0.31	0.30	0.14	0.27 to 0.33

¹ Adjusted to 113.4 kg through regression of backfat on off-test weight within breed

^a σ_a^2 = direct additive genetic variance; σ_e^2 = residual variance; h_a^2 = direct heritability

^b Highest posterior density (95%) interval

Table 3.7. Estimates of variance components^a and heritabilities for temperament scores: Load Score (LS), Scale Score (SS), Vocal Score (VS), and performance traits: Backfat (BF), Loin Depth (LD), Days to 113.4 kg (DAYS), and Percent Fat-Free Lean (LEAN) for Yorkshire

Trait	σ_a^2			h_a^2	σ_e^2		
	Mean	S.D.	HPD ^b		Mean	S.D.	HPD ^b
LS	0.11	0.11	0.00 to 0.37	0.05	1.96	0.28	1.65 to 2.73
SS	0.19	0.13	0.00 to 0.43	0.10	1.76	0.23	1.31 to 2.19
VS	0.27	0.20	0.01 to 0.66	0.21	1.01	0.07	0.88 to 1.14
BF ¹ (mm)	0.23	0.02	0.18 to 0.28	0.35	0.43	0.02	0.40 to 0.46
LD ¹ (mm)	0.01	0.01	0.01 to 0.02	0.47	0.01	0.01	0.01 to 0.02
DAYS (d)	42.14	2.28	38.03 to 46.86	0.68	19.80	1.22	17.53 to 22.33
LEAN (%)	0.82	0.35	0.76 to 0.89	0.68	0.39	0.02	0.35 to 0.42

¹ Adjusted to 113.4 kg through regression of backfat on off-test weight within breed

^a σ_a^2 = direct additive genetic variance; σ_e^2 = residual variance; h_a^2 = direct heritability

^b Highest posterior density (95%) interval

Table 3.8. Covariance estimates^a of temperament scores: Load Score (LS), Scale Score (SS), Vocal Score (VS), and performance traits: Backfat (BF), Loin Depth (LD), Days to 113.4 kg (DAYS), and Percent Fat-Free Lean (LEAN) for Chester White

Traits ^{1,2}	$\sigma_{a1,a2}$ (mean)	S.D.	HPD ^b	r_{a1a2}	$\sigma_{e1,e2}$ (mean)
LS – SS	-0.06	0.09	-0.24 to 0.12	-0.26	0.29
LS – VS	0.09	0.11	-0.12 to 0.34	0.44	0.26
LS – BF	0.02	0.01	-0.01 to 0.04	0.43	-0.02
LS – LD	0.02	0.02	-0.01 to 0.05	0.32	-0.01
LS – DAYS	-0.20	1.64	-3.85 to 2.88	-0.06	-0.96
LS – LEAN	-0.06	0.41	-0.33 to 0.23	-0.14	0.20
SS – VS	0.16	0.14	-0.10 to 0.43	0.42	0.54
SS – BF	-0.02	0.02	-0.05 to 0.01	-0.25	-0.02
SS – LD	0.02	0.02	-0.02 to 0.06	0.20	-0.02
SS – DAYS	3.28	1.73	-0.02 to 6.60	0.49	-2.93
SS – LEAN	0.45	0.18	0.11 to 0.80	0.53	0.01
VS – BF	-0.01	0.02	-0.04 to 0.03	-0.11	-0.01
VS – LD	0.02	0.02	-0.03 to 0.06	0.23	-0.01
VS – DAYS	1.84	2.38	-2.76 to 6.39	0.30	-1.72
VS – LEAN	0.18	0.19	-0.17 to 0.56	0.29	-0.01
BF – LD	-0.01	0.00	-0.01 to 0.00	-0.09	-0.00
BF – DAYS	-0.15	0.13	-0.40 to 0.11	-0.07	-0.17
BF – LEAN	0.01	0.01	-0.02 to 0.04	0.06	-0.03
LD – DAYS	0.15	0.01	0.12 to 0.17	0.48	0.08
LD – LEAN	0.00	0.00	-0.01 to 0.01	0.01	0.01
DAYS – LEAN	0.46	0.11	0.26 to 0.67	0.23	0.60

¹ LS= load score, SS= scale score, VS= vocal score, BF= adjusted backfat (mm), LD= adjusted loin depth (mm), DAYS= days to 113.4 kilograms (d), LEAN= estimated percent fat-free lean (%). ² BF and LD adjusted to 113.4 kg

^a $\sigma_{a1,a2}$ = direct genetic covariance; $\sigma_{e1,e2}$ = residual covariance; r_{a1a2} = direct genetic correlation

^b Highest posterior density (95%) interval

Table 3.9. Covariance estimates^a of temperament scores: Load Score (LS), Scale Score (SS), Vocal Score (VS), and performance traits: Backfat (BF), Loin Depth (LD), Days to 113.4 kg (DAYS), and Percent Fat-Free Lean (LEAN) for Duroc

Traits ^{1,2}	$\sigma_{a1,a2}$ (mean)	S.D.	HPD ^b	r_{a1a2}	$\sigma_{e1,e2}$ (mean)
LS – SS	0.05	0.05	-0.04 to 0.14	0.41	0.12
LS – VS	0.05	0.10	-0.14 to 0.23	0.21	0.24
LS – BF	-0.01	0.01	-0.03 to 0.01	-0.28	0.00
LS – LD	-0.00	0.01	-0.03 to 0.02	-0.07	0.00
LS – DAYS	1.41	0.98	-0.61 to 3.25	0.43	0.14
LS – LEAN	0.08	0.08	-0.09 to 0.26	0.26	0.02
SS – VS	0.16	0.08	0.02 to 0.32	0.75	0.53
SS – BF	-0.01	0.01	-0.03 to 0.01	-0.37	-0.02
SS – LD	-0.01	0.01	-0.04 to 0.01	-0.29	-0.02
SS – DAYS	-0.19	0.86	-1.82 to 1.47	-0.07	-0.96
SS – LEAN	0.09	0.09	-0.08 to 0.26	0.26	0.13
VS – BF	-0.01	0.02	-0.04 to 0.02	-0.30	-0.01
VS – LD	-0.04	0.02	-0.08 to 0.02	-0.57	0.03
VS – DAYS	-2.08	1.95	-5.54 to 0.97	-0.38	32.64
VS – LEAN	-0.15	0.13	-0.42 to 0.08	-0.32	0.27
BF – LD	-0.01	0.00	-0.01 to 0.00	-0.11	0.00
BF – DAYS	0.09	0.11	-0.12 to 0.31	0.04	0.00
BF – LEAN	-0.03	0.01	-0.05 to -0.01	-0.09	-0.03
LD – DAYS	0.06	0.01	0.04 to 0.09	0.15	0.01
LD – LEAN	0.03	0.00	0.03 to 0.04	0.59	0.01
DAYS – LEAN	1.09	0.09	0.92 to 1.27	0.54	0.78

¹ LS= load score, SS= scale score, VS= vocal score, BF= adjusted backfat (mm), LD= adjusted loin depth (mm), DAYS= days to 113.4 kilograms (d), LEAN= estimated percent fat-free lean (%). ² BF and LD adjusted to 113.4 kg

^a $\sigma_{a1,a2}$ = direct genetic covariance; $\sigma_{e1,e2}$ = residual covariance; r_{a1a2} = direct genetic correlation

^b Highest posterior density (95%) interval

Table 3.10. Covariance estimates^a of temperament scores: Load Score (LS), Scale Score (SS), Vocal Score (VS), and performance traits: Backfat (BF), Loin Depth (LD), Days to 113.4 kg (DAYS), and Percent Fat-Free Lean (LEAN) for Landrace

Traits ^{1,2}	$\sigma_{a1,a2}$ (mean)	S.D.	HPD ^b	r_{a1a2}	$\sigma_{e1,e2}$ (mean)
LS – SS	0.15	0.11	-0.03 to 0.37	0.64	0.35
LS – VS	0.35	0.23	-0.02 to 0.77	0.72	0.07
LS – BF	0.01	0.01	-0.02 to 0.04	0.20	0.01
LS – LD	0.00	0.03	-0.05 to 0.05	0.01	0.04
LS – DAYS	-1.89	1.34	-4.71 to 0.61	-0.58	1.03
LS – LEAN	-0.18	0.15	-0.45 to 0.13	-0.52	0.12
SS – VS	0.10	0.07	-0.14 to 0.15	0.31	0.73
SS – BF	0.01	0.01	-0.01 to 0.03	0.38	-0.04
SS – LD	-0.03	0.02	-0.07 to 0.00	-0.52	0.01
SS – DAYS	-0.86	1.19	-3.09 to 1.37	-0.36	1.82
SS – LEAN	0.20	0.10	-0.41 to 0.00	-0.65	0.44
VS – BF	0.02	0.02	-0.02 to 0.05	0.28	-0.02
VS – LD	-0.01	0.03	-0.08 to 0.06	-0.04	-0.18
VS – DAYS	-0.12	1.67	-3.23 to 3.19	-0.02	1.49
VS – LEAN	-0.19	0.18	-0.58 to 0.13	-0.30	0.15
BF – LD	0.00	0.00	0.00 to 0.01	0.03	0.00
BF – DAYS	-0.26	0.14	-0.54 to 0.00	-0.12	-0.01
BF – LEAN	0.00	0.01	-0.02 to 0.28	0.01	-0.02
LD – DAYS	0.11	0.03	0.05 to 0.17	0.30	-0.03
LD – LEAN	0.01	0.00	0.00 to 0.01	0.27	0.01
DAYS – LEAN	0.74	0.19	0.40 to 1.14	0.41	1.48

¹ LS= load score, SS= scale score, VS= vocal score, BF= adjusted backfat (mm), LD= adjusted loin depth (mm), DAYS= days to 113.4 kilograms (d), LEAN= estimated percent fat-free lean (%). ² BF and LD adjusted to 113.4 kg

^a $\sigma_{a1,a2}$ = direct genetic covariance; $\sigma_{e1,e2}$ = residual covariance; r_{a1a2} = direct genetic correlation

^b Highest posterior density (95%) interval

Table 3.11. Covariance estimates^a of temperament scores: Load Score (LS), Scale Score (SS), Vocal Score (VS), and performance traits: Backfat (BF), Loin Depth (LD), Days to 113.4 kg (DAYS), and Percent Fat-Free Lean (LEAN) for Yorkshire

Traits ^{1,2}	$\sigma_{a1,a2}$ (mean)	S.D.	HPD ^b	r_{a1a2}	$\sigma_{e1,e2}$ (mean)
LS – SS	-0.04	0.10	-0.24 to 0.13	-0.22	0.21
LS – VS	0.03	0.11	-0.17 to 0.24	0.13	0.10
LS – BF	0.01	0.02	-0.03 to 0.03	0.12	0.00
LS – LD	-0.01	0.02	-0.06 to 0.03	-0.13	0.00
LS – DAYS	0.68	2.19	-3.73 to 4.81	0.19	-2.54
LS – LEAN	0.05	0.19	-0.28 to 0.46	0.13	-0.08
SS – VS	0.07	0.11	-0.14 to 0.30	0.30	0.69
SS – BF	-0.01	0.02	-0.04 to 0.02	-0.16	-0.02
SS – LD	-0.01	-0.02	-0.06 to 0.03	-0.21	-0.04
SS – DAYS	1.56	2.26	-2.89 to 6.25	-0.26	-0.32
SS – LEAN	0.09	0.19	-0.27 to 0.46	0.17	0.09
VS – BF	-0.05	-0.02	-0.10 to -0.01	-0.78	0.04
VS – LD	-0.05	0.02	-0.10 to -0.01	-0.68	0.02
VS – DAYS	0.89	2.45	-3.95 to 5.64	0.16	-0.63
VS – LEAN	0.30	0.22	-0.13 to 0.74	0.50	-0.34
BF – LD	0.01	0.00	-0.01 to 0.01	0.03	0.00
BF – DAYS	0.12	0.18	-0.24 to 0.46	0.04	0.00
BF – LEAN	0.06	0.02	-0.02 to -0.10	0.13	0.00
LD – DAYS	-0.11	0.03	-0.16 to 0.05	-0.21	0.00
LD – LEAN	-0.01	0.00	-0.01 to 0.01	-0.02	0.00
DAYS – LEAN	4.33	0.23	3.87 to 4.73	0.73	0.00

¹ LS= load score, SS= scale score, VS= vocal score, BF= adjusted backfat (mm), LD= adjusted loin depth (mm), DAYS= days to 113.4 kilograms (d), LEAN= estimated percent fat-free lean (%). ² BF and LD adjusted to 113.4 kg

^a $\sigma_{a1,a2}$ = direct genetic covariance; $\sigma_{e1,e2}$ = residual covariance; r_{a1a2} = direct genetic correlation

^b Highest posterior density (95%) interval

CHAPTER 4

GENERAL CONCLUSIONS

The swine industry has become more integrated, encouraging the standardization of swine facilities and management practices, which were developed to create a better living environment for the pig. However, facilities and management practices have fallen under public scrutiny, and the swine industry continues efforts to find practices that ensure adequate housing, ethical animal husbandry and handling practices that minimize stress are utilized, while maintaining profit for the producer.

Selection programs in the swine industry are designed to identify pigs that produce multiple, large litters of quick and efficient growing pigs that produce high quality lean meat, increasing profits for the producer. Pigs that excel in performance are selected, but temperament often gets ignored. In cattle it has been speculated that intense selection for growth and leanness has increased problems with temperament.

The objectives of this study were 1) to determine breed differences in three temperament traits measured during a performance test and their phenotypic relationships with performance, and 2) estimate genetic parameters of temperament scores and their genetic relationship with performance.

Three temperament scores, load score, scale score, and vocal score, were recorded during a performance test at approximately 185 days of age. Temperament was scored on a 5 point scale, and after initial analysis vocal score was determined to be best described by 2 categories, vocal or non-vocal.

In chapter two breed and sex differences were calculated for three temperament scores as the likelihood that one breed would be more likely to have an increase in temperament score compared to another breed. Gilts were more likely to be vocal than boars, but no differences for load or scale scores were found for sex. The order in which pigs were loaded affected the likelihood that pigs would be more difficult to load. Pigs that were loaded last were more likely to have an increase in load score than pigs loaded at the beginning.

Landrace were the most temperamental breed and were significantly more likely to become difficult to load than Duroc and Yorkshire. Landrace were more likely than Chester White, Duroc and Yorkshire to have an increase in scale score and become vocal. Chester White were more difficult to load and were more likely to be active in the scale than Duroc and Yorkshire, and more likely to become vocal than Duroc. Yorkshires were more likely to have an increase in all temperament scores than Durocs.

Previous studies indicated calmer animals grow faster than temperamental animals, but have less favorable carcass composition. In this project, as load score increased, days to 113.4 kg and loin depth increased. Pigs that had a scale score of 1 had the largest loin depth but were the fattest. As scale score increased pigs became leaner but grew slower. Pigs that were non-vocal tended to have more backfat, larger loin depth, grew faster, and had a lower percent fat-free lean than pigs that were vocal. Results of this study indicate as temperament scores increased, pigs tended to become leaner, have smaller loin depth, and grow slower.

In chapter three, heritability for the three temperament traits and the genetic correlations between temperament and performance traits were estimated for each of the four

breeds. Load score consistently had a low heritability (0.06) for all breeds, and progress would be slow through direct selection. Estimates of heritability were also low (0.09) for scale score in all breeds with the exception of Chester White, in which scale score was moderately heritable (0.22). The heritability estimates for vocal score were moderate (0.27) and tended to be consistent across breeds. Selection for vocal score would provide the greatest potential for genetic progress in all breeds. Genetic correlations suggested positive relationships between the three temperament scores, indicating that as one score increased so would the others.

Genetic correlations between temperament traits and performance traits varied between breeds. The correlations between load score and performance fluctuated greatly, which could be due to low genetic variance estimates for load score which is suggested to have a large environmental component.

Prior to this study temperament traits had not been measured in these populations. In general, selection for decreased backfat would result in an increase in activity and vocalization during a performance test. However, in Landrace pigs which were leaner were also less active during a performance test. With the exception of the Chester White breed, an increase in loin depth suggested a decrease in loading activity, and decrease in activity and vocalization in the scale would occur through indirect selection. Though the relationship between growth and temperament was inconsistent across breeds, selection for faster growing pigs generally suggested an increase in activity while in the scale and less activity during loading. Selection for increased fat-free lean would likely decrease activity and vocalization in Landrace and Duroc, but increase activity in Chester White and Yorkshire.

This study revealed significant differences in temperament between breeds, and demonstrated that there is a genetic component in pig temperament during a performance test. Direct selection for temperament can be effective, and potentially alter pig behavior during a performance test. Current selection programs for improved performance may have an effect on temperament, though effects vary between breeds. To understand the effect of selection for temperament on performance and on other relevant pig behaviors further research must be conducted.

APPENDIX

Table A.1. Scoring requirements for temperament scores

Temperament Level	Load Score	Scale Score	Vocal Score
1	Walked into scale with little persuasion from farm personnel	No movement and ultrasound was completed quickly	No Vocalization during time in the scale
2	After identification was read, pig entered scale with multiple taps on back	Movements were slow, and head moved side to side	A few random soft vocalizations (low grunts)
3	Pig needed many taps on back or was, physically pushed into the scale by farm personnel	Movements were moderate throughout. Move from front to back of scale.	Constant unexcited soft vocalizations (low constant grunt)
4	Made attempt(s) at escaping back into pen during loading process, and may be vocal	Moves were continuous and very fast. Pig slammed head against scale door and attempted to turn around in scale	Infrequent loud vocalization or high pitched squeals
5	Attempted to jump out of pen or holding area, escaped back into pen, or if electric prod was used	Pig tried to jump out of the top of the scale or successfully turned around in the scale	Constant excited or high pitch vocalizations

Table A.2. Frequency^a of Load Scores by breed and sex

Load Score	<u>Breed</u>				<u>Sex</u>	
	Chester White	Duroc	Landrace	Yorkshire	Gilts	Boars
1	39.4	50.3	40.8	46.6	45.6	44.8
2	29.7	27.4	26.6	28.8	27.6	28.5
3	15.3	10.1	14.7	12.0	12.5	12.7
4	7.4	6.8	11.5	5.6	7.6	7.7
5	8.2	5.4	6.4	7.0	6.7	6.3

^a Frequencies listed as percentage of pigs measured

Table A.3. Frequency^a of Scale Scores by breed and sex

Scale Score	<u>Breed</u>				<u>Sex</u>	
	Chester White	Duroc	Landrace	Yorkshire	Gilts	Boars
1	34.4	50.2	23.0	43.2	39.0	41.3
2	31.7	28.8	30.0	29.5	29.9	29.7
3	20.5	14.0	22.0	13.3	18.0	15.5
4	7.4	4.2	12.6	7.3	6.5	8.0
5	6.0	2.6	12.4	6.7	6.6	5.5

^a Frequencies listed as percentage of pigs measured

Table A.4. Frequency^a of Vocal Scores by breed and sex

Vocal Score	<u>Breed</u>				<u>Sex</u>	
	Chester White	Duroc	Landrace	Yorkshire	Gilts	Boars
1	90.0	94.1	79.4	89.8	87.9	91.6
2	3.4	3.0	4.5	3.5	4.0	2.8
3	2.8	1.1	4.1	2.6	2.6	2.1
4	2.7	1.2	6.2	2.7	3.1	2.4
5	1.1	0.6	5.8	1.4	2.4	1.2

^a Frequencies listed as percentage of pigs measured

Table A.5. Unadjusted Means, Standard Deviations, Minimums, and Maximums for Chester White

Variable	Mean	<u>Gilts¹</u>			Mean	<u>Boars²</u>		
		S.D.	Minimum	Maximum		S.D.	Minimum	Maximum
Load Score	2.19	1.27	1.00	5.00	2.09	1.21	1.00	5.00
Scale Score	2.19	1.17	1.00	5.00	2.20	1.15	1.00	5.00
Vocal Score	1.11	0.31	1.00	2.00	1.09	0.28	1.00	2.00
Backfat (mm)	23.41	4.56	11.58	40.03	21.84	4.57	9.64	44.12
Loin Depth (mm)	59.65	6.54	41.42	82.50	58.11	6.55	36.50	80.17
Days to 113.4 kg (d)	189.9	14.1	153.0	230.0	184.0	13.3	151.7	224.4
Percent Lean (%)	48.27	1.80	42.52	53.56	48.37	1.75	40.93	53.37
Weight at off-test (kg)	109.3	10.7	86.2	145.2	113.7	11.7	86.2	147.4
Age at off-test (d)	183.4	162.0	162.0	212.0	183.3	9.5	164.0	208.0

¹ n= 648² n= 428

Table A.6. Unadjusted Means, Standard Deviations, Minimums, and Maximums for Duroc

Variable	Mean	S.D.	<u>Gilts¹</u>		Mean	S.D.	<u>Boars²</u>	
			Minimum	Maximum			Minimum	Maximum
Load Score	1.83	1.14	1.00	5.00	1.98	1.19	1.00	5.00
Scale Score	1.84	1.01	1.00	5.00	1.75	0.99	1.00	5.00
Vocal Score	1.07	0.26	1.00	2.00	1.04	0.20	1.00	2.00
Backfat (cm)	20.71	4.47	10.91	39.66	20.55	4.84	7.21	42.98
Loin Depth (cm)	64.36	6.99	44.65	89.43	61.65	6.98	40.28	89.43
Days to 113.4 kg (d)	190.5	13.7	150.2	234.9	182.4	12.6	152.4	227.3
Percent Lean (%)	49.44	1.69	42.61	54.91	48.77	1.70	40.99	54.07
Weight at off-test (kg)	111.2	10.8	86.2	145.2	119.0	12.6	86.2	147.4
Age at off-test (d)	186.6	8.8	165.0	213.0	187.9	10.5	160.0	210.0

¹ n= 986² n= 846

Table A.7. Unadjusted Means, Standard Deviations, Minimums, and Maximums for Landrace

Variable	Mean	S.D.	<u>Gilts¹</u>		Mean	S.D.	<u>Boars²</u>	
			Minimum	Maximum			Minimum	Maximum
Load Score	2.19	1.24	1.00	5.00	2.12	1.27	1.00	5.00
Scale Score	2.59	1.29	1.00	5.00	2.65	1.32	1.00	5.00
Vocal Score	1.24	0.43	1.00	2.00	1.17	0.37	1.00	2.00
Backfat (cm)	17.59	3.67	8.38	33.90	17.69	3.81	8.12	33.65
Loin Depth (cm)	64.20	7.12	34.17	89.26	62.11	6.83	47.33	82.49
Days to 113.4 kg (d)	194.0	14.9	149.8	241.3	187.8	13.7	157.5	238.1
Percent Lean (%)	50.68	1.53	44.34	54.44	50.15	1.48	44.86	54.31
Weight at off-test (kg)	107.4	10.6	83.9	138.3	112.9	12.5	86.2	147.4
Age at off-test (d)	184.8	9.3	161.0	207.0	186.0	10.4	169.0	208.0

¹ n= 519² n= 422

Table A.8. Unadjusted Means, Standard Deviations, Minimums, and Maximums for Yorkshire

Variable	Mean	<u>Gilts¹</u>			Mean	<u>Boars²</u>		
		S.D.	Minimum	Maximum		S.D.	Minimum	Maximum
Load Score	2.01	1.24	1.00	5.00	1.94	1.15	1.00	5.00
Scale Score	2.10	1.26	1.00	5.00	1.98	1.14	1.00	5.00
Vocal Score	1.11	0.32	1.00	2.00	1.08	0.28	1.00	2.00
Backfat (cm)	19.90	4.19	10.87	37.79	19.32	4.34	7.52	40.25
Loin Depth (cm)	63.33	7.04	41.54	86.15	60.17	6.41	45.35	79.31
Days to 113.4 kg (d)	196.0	15.1	143.3	243.8	186.7	14.6	148.5	228.1
Percent Lean (%)	50.00	1.68	42.91	54.04	49.43	1.69	42.14	53.95
Weight at off-test (kg)	106.2	11.3	83.9	147.4	113.3	13.1	86.2	147.4
Age at off-test (d)	184.9	9.1	163.0	211.0	185.3	10.0	163.0	208.0

¹ n= 524² n= 401

Table A.9. Heritabilities (on diagonal) and Genetic Correlations (above diagonal) between temperament and performance traits in Chester White

Trait ¹	LS	SS	VS	BF ²	LD ²	DAYS	LEAN
LS	0.05	-0.26	0.44	0.43	0.32	-0.06	-0.14
SS		0.22	0.42	-0.25	0.20	0.49	0.53
VS			0.27	-0.11	0.23	0.30	0.29
BF ²				0.34	-0.09	-0.07	0.06
LD ²					0.42	0.48	0.01
DAYS						0.53	0.23
LEAN							0.43

¹ LS= load score, SS= scale score, VS= vocal score, BF= adjusted backfat (mm), LD= adjusted loin depth (mm), DAYS= days to 113.4 kilograms (d), LEAN= estimated percent fat-free lean (%).

² Adjusted to 113.4 kg through regression on off-test weight within each breed

Table A.10. Heritabilities (on the diagonal) and Genetic Correlations (above diagonal) between temperament and performance traits in Duroc

Trait ¹	LS	SS	VS	BF ²	LD ²	DAYS	LEAN
LS	0.06	0.41	0.21	-0.28	-0.07	0.43	0.26
SS		0.09	0.75	-0.37	-0.29	-0.07	0.26
VS			0.24	-0.30	-0.57	-0.38	-0.32
BF ²				0.38	-0.11	0.04	-0.09
LD ²					0.62	0.15	0.59
DAYS						0.51	0.54
LEAN							0.50

¹ LS= load score, SS= scale score, VS= vocal score, BF= adjusted backfat (mm), LD= adjusted loin depth (mm), DAYS= days to 113.4 kilograms (d), LEAN= estimated percent fat-free lean (%).

² Adjusted to 113.4 kg through regression on off-test weight within each breed

Table A.11. Heritabilities (on the diagonal) and Genetic Correlations (above diagonal) between temperament and performance traits in Landrace

Trait ¹	LS	SS	VS	BF ²	LD ²	DAYS	LEAN
LS	0.06	0.64	0.72	0.20	0.01	-0.58	-0.52
SS		0.09	0.31	0.38	-0.52	-0.36	-0.65
VS			0.37	0.28	-0.04	-0.02	-0.30
BF ²				0.47	0.03	-0.12	0.01
LD ²					0.40	0.30	0.27
DAYS						0.51	0.41
LEAN							0.31

¹ LS= load score, SS= scale score, VS= vocal score, BF= adjusted backfat (mm), LD= adjusted loin depth (mm), DAYS= days to 113.4 kilograms (d), LEAN= estimated percent fat-free lean (%).

² Adjusted to 113.4 kg through regression on off-test weight within each breed

Table A.12. Heritabilities (on the diagonal) and Genetic Correlations (above diagonal) between temperament and performance traits in Yorkshire

Trait ¹	LS	SS	VS	BF ²	LD ²	DAYS	LEAN
LS	0.05	-0.22	0.13	0.12	-0.13	0.19	0.13
SS		0.10	0.30	-0.16	-0.21	-0.26	0.17
VS			0.21	-0.78	-0.68	0.16	0.50
BF ²				0.35	0.03	0.04	0.13
LD ²					0.47	-0.21	-0.02
DAYS						0.68	0.73
LEAN							0.68

¹ LS= load score, SS= scale score, VS= vocal score, BF= adjusted backfat (mm), LD= adjusted loin depth (mm), DAYS= days to 113.4 kilograms (d), LEAN= estimated percent fat-free lean (%).

² Adjusted to 113.4 kg through regression on off-test weight within each breed

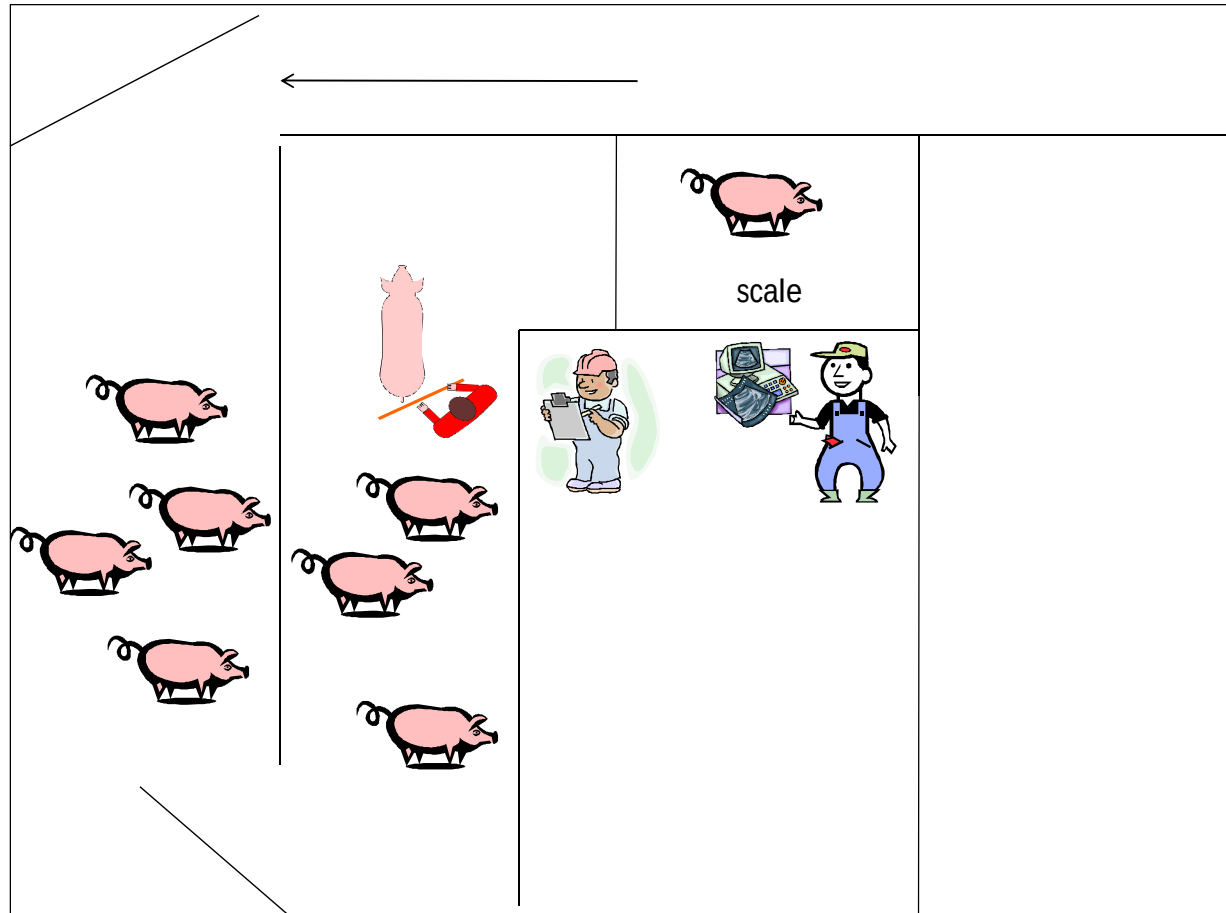


Figure A.1. Pig flow during off-test and temperament scoring procedures

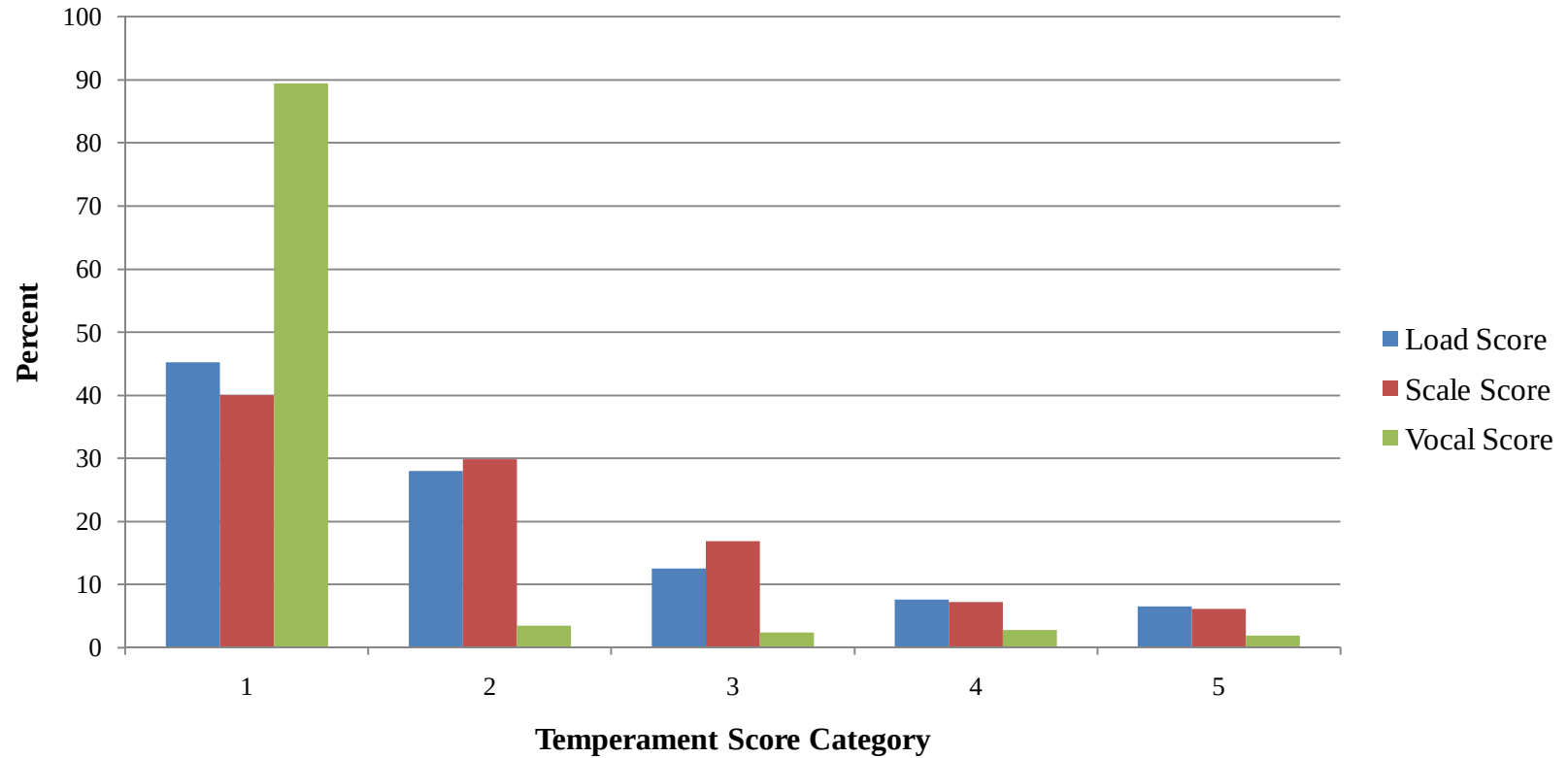


Figure A.2. Frequency of temperament scores at each level of scoring (n = 4,774)

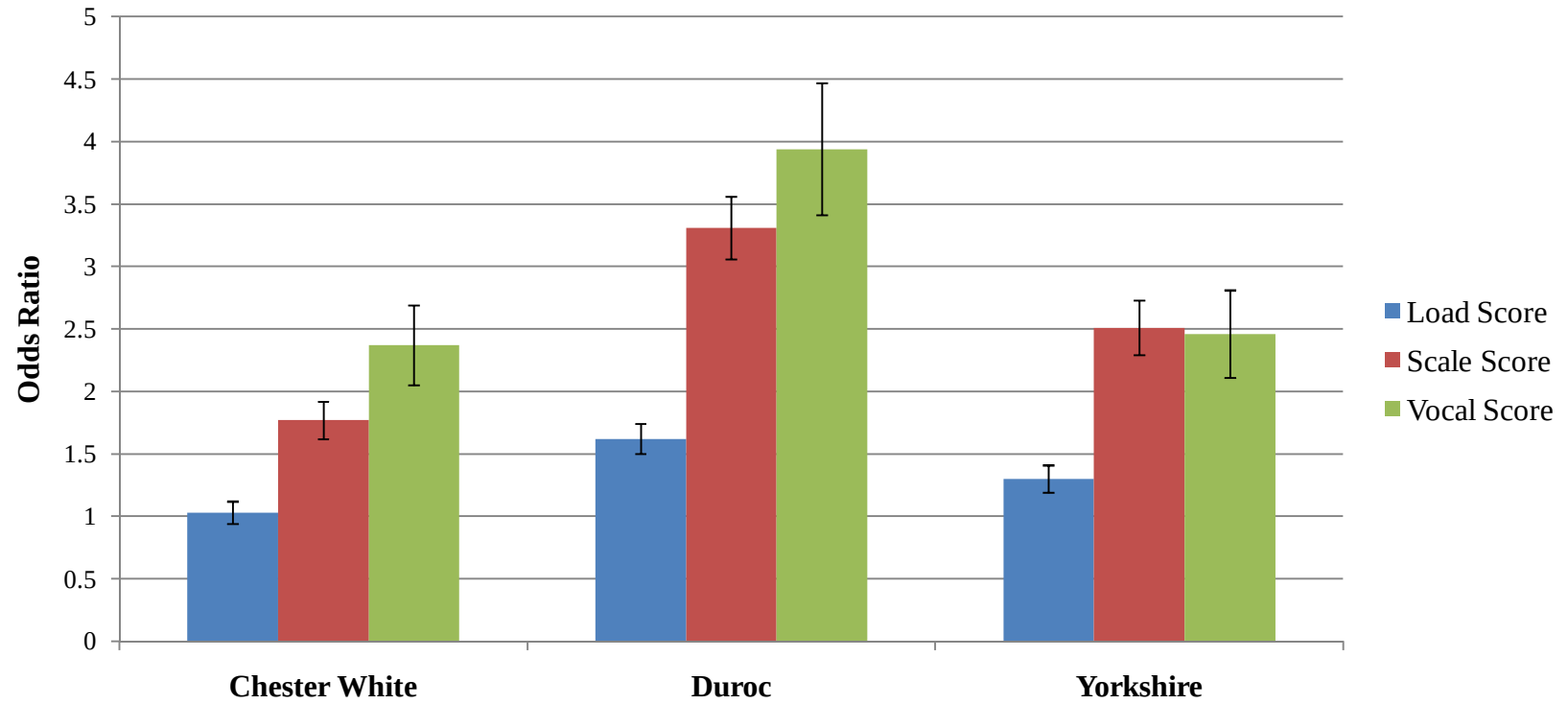


Figure A.3. Likelihood, represented as odds-ratios, of Landrace having an increase in temperament score compared to Chester White, Duroc and Yorkshire

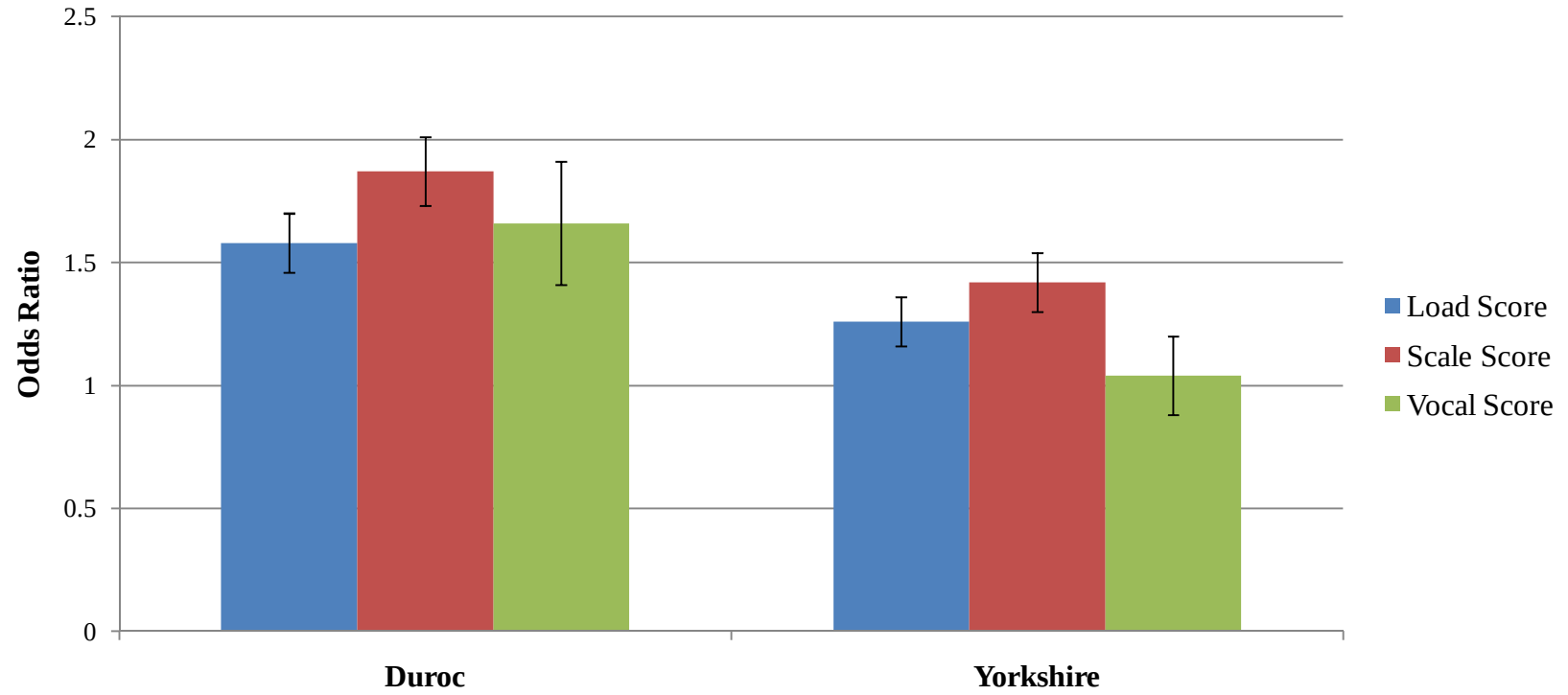


Figure A. 4. Likelihood, represented as odds-ratios, of Chester White having an increase in temperament score compared to Duroc and Yorkshire

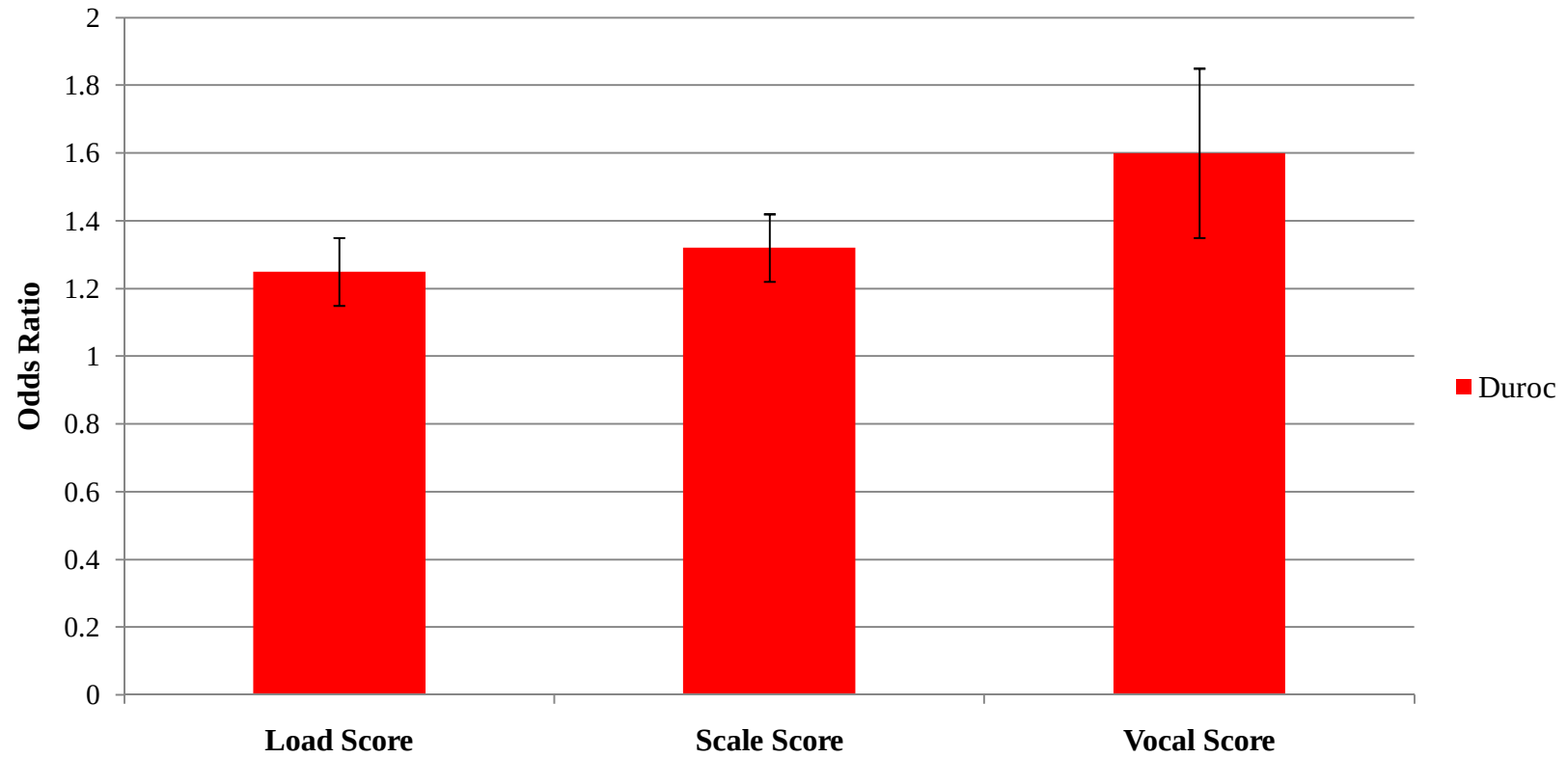


Figure A. 5. Likelihood, represented as odds-ratios, of Yorkshire having an increase in temperament score compared to Duroc