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The effect of selection for residual feed intake on general behavioral activity, occurrence of lesions, scale activity and exit score in Yorkshire gilts

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CHAPTER 4. THE EFFECT OF SELECTION FOR RESIDUAL FEED INTAKE ON SCALE ACTIVITY AND EXIT SCORE IN YORKSHIRE GILTS

Abstract

Implications

Introduction

Materials and methods

Experimental design
Animals
Housing and feeding
Indoor environmental measurements
Behavior scoring

Results and discussion

Indoor environmental measurements
Scale activity scoring
Genetic line
Entire population of gilts over all rounds
Scale exit score

Conclusion

Literature cited

CHAPTER 5. GENERAL SUMMARY
ABSTRACT

The objectives of these studies were to determine the effect of selection for reduced residual feed intake (RFI) on activity, lesion scores and temperament in gilts. Purebred Yorkshire gilts were utilized (n=192). Half were from a line that had been selected for five generations for reduced RFI (LRFI) and half were from a randomly bred line, which served as a control (CRFI). On the day of placement there were no differences between the lines regarding general activity, however LRFI gilts had lower lesion scores. Over the trial, the LRFI gilts had lower overall activity, but lesions were not different between lines. The LRFI gilts scored lower during an initial temperament score. While both lines’ temperament scores decreased over the trial, CRFI gilts had a greater percentage decrease and scored lower than the LRFI gilts by the end. Selection for reduced RFI reduced activity and did not detrimentally affect temperament.
CHAPTER 1. GENERAL INTRODUCTION

Few factors that contribute to residual feed intake in the pig have been identified. In an effort to detect and understand these factors a line of purebred Yorkshire gilts has been developed at Iowa State University along with a randomly selected bred line to serve as a control. By identify and examining differences between these lines, correlations can be established on the affect of selection for reduced residual feed intake.

The literature review contained in this thesis addresses two major areas of research. The first area focuses on how residual feed intake (RFI) relates to general activity. In order to adequately address this several subcomponents will be examined including, the development and refinement of RFI, how RFI has been linked to a variety of animals and why RFI is an important consideration. The second area will concentrate on temperament. Specifically it will examine, what is temperament, how we can score and evaluate it in an animal and why temperament may be important for a RFI selection program. Chapter Three titled, “The effect of selection for residual feed intake on general behavioral activity and the occurrence of lesion in Yorkshire gilts” will examine the effect of selection for reduced residual feed intake (RFI) on general behavioral activities and lesion scores for gilts in their home pen. Chapter Four titled, “The effect of selection for residual feed intake on scale activity and exit score in Yorkshire gilts” will determine the relationship between scale activity and exit scores between the developed
genetic lines. The findings from these investigations maybe beneficial for future RFI selection programs and could be added to the list of previously identified factors that may contribute to the variation in RFI of the grow-finish gilt.
CHAPTER 2. LITERATURE REVIEW

This literature review addresses two major areas of research. The first area focuses on how residual feed intake (RFI) relates to general activity. In order to adequately address this, several subcomponents will be examined, the development and refinement of RFI, how RFI has been linked to a variety of animals and why RFI is an important consideration. The second area will concentrate on temperament. Specifically it will examine, what is temperament, how can we score and evaluate animal temperament and why temperament may be important for a RFI selection program.

Development and refinement of the residual feed intake concept

Residual feed intake is based fundamentally on the concepts related to feed efficiency. Feed efficiency is the amount of gain made per unit of feed. It is measured by kilograms of feed required per kilogram of liveweight gain (Taylor and Field, 2004). Selection of animals for improved feed efficiency has been documented since 1936 (Winters, 1936). The author noted in cattle a high relationship between rate of gain and efficiency of gain or, simply put, cattle that gain faster require fewer kilograms of feed per kilogram of gain. Feed efficiency has therefore been used as a measure to improve genetics of farm animals and in turn enable producers to decrease the amount of feed required to produce a set amount of gain.
Genetic correlation estimates between feed intake and production traits show that genetic variation in feed intake has both production and non-production components. The correlations between feed intake and production traits are typically high, ranging from 0.6 to 0.8 (van der Heide et al., 1999). Thus, a large proportion of the variation in feed intake is production related. However, this also means that a proportion of feed intake is not related to production. This proportion has been termed Residual Feed Intake (RFI; van der Heide, et. al., 1999) or defined as “[RFI is] a measure of feed efficiency that is independent of the level of production” (Herd and Arthur, 2009). Selection for RFI and the use of this terminology did not begin until several years after selection for feed efficiency. One of the first published reports specifically identifying RFI was by Koch et al. (1963). They examined 1324 bull and heifer calves from experimental breeding herds maintained at the Fort Robinson Beef Cattle Research Station, Nebraska Agricultural Experiment Station and Fort Reno Livestock Research Station. Breeds examined included Herefords, Angus and Shorthorns. The authors note that variations in efficiency could result from several factors including variations in body weight, resulting in differences in maintenance, composition of gain, feed consumption and environment. They noted in their analysis there were two parts to feed efficiency, one related to feed consumption and gain and the other they termed residual.

RFI can be calculated as a residual term of a multiple linear regression of feed intake on production and body weight (van der Heide et al. 1999. However over several years, RFI has developed and been adjusted as knowledge of what
Factors contribute to RFI expands. Most notably, body composition has been included in many models. Taylor and Field (2004) estimated that it takes about 2.25 times as much energy to produce 1 kilogram of fat as to produce 1 kilogram of protein tissue. Thus, selection for improved feed efficiency has resulted in a leaner animal. From this, it is recognized that one way for an animal to achieve a lower RFI, if RFI is not adjusted for composition, is by producing less fat and more muscle. However, researchers have recognized that simply lowering fat (both intramuscular and backfat) is not necessarily desirable. Many researchers have refined RFI when related to swine to include fat, either backfat, intramuscular fat, or both (estimated through the use of ultrasound) into their models for RFI (de Haer et al., 1993, Johnson et al. 1999, Rauw et al., 2006a, Cai et al., 2008), thus eliminating this easy gain for reduced RFI simply by changing the body-fat composition. For example, Johnson et al. (1999) examined production records of Large White boars. These boars were individually housed around 100 days of age and on test for 77 days. The authors reported that RFI had a negative genetic correlated to loin eye area ranging from -0.31 to -0.51. They also found that backfat was positively correlated with RFI, particularly when RFI was not adjusted for backfat and loin eye area (0.67), indicating selection for decreased RFI may also result in decreased backfat.
Behavioral contributions to RFI

Feed intake, rate and number of visits

Behavioral differences in animals have been correlated to RFI. Robinson and Oddy (2004) used records from the Cattle and Beef Industry Cooperative Research Center research herd, this included 524 steers and 172 heifers of tropically adapted breeds and 785 steers of temperament breeds. The researchers demonstrated a tendency for cattle with lower RFI within a breed to eat fewer meals per day (estimated genetic correlation \( r = 0.43 \)). In addition, these cattle had less subcutaneous fat. Furthermore, these authors reported a positive genetic correlation between low RFI and the amount of time they engaged in eating (0.35), but their eating rate did not seem to be related to RFI. A total of 304 group housed (eight pigs per pen), mixed sex, Dutch Landrace and Great Yorkshire pigs were examined by de Haer et al. (1993). They reported that the pig’s eating patterns: time spent eating, number of meals per day and number of visits to the feeder contribute to RFI, with phenotypic correlations of 0.64, 0.45 and 0.51 respectively. The authors concluded that 44% of the variation of RFI in these pigs was accounted for by the number of visits to the feeders and daily eating time. This was in contrast to Rauw et al. (2006a), who concluded that for a population of 200 Duroc barrows, feed intake rate and amount consumed daily did not affect RFI. These authors examined average daily feed intake, daily feeding time and daily feeding frequency, while body weight and backfat thickness were measured on
days 2, 16, 39, 67, 88, and 106 of the study. They did not find a significant relationship between feed intake in the first and fourth period, first and fifth period, or between the second and fifth periods. All other phenotypic correlations for feed intake and time periods ranged from \((r = 0.36\) to \(0.89; P < 0.001\)). Residual feed intake between the first and fourth period, first and fifth periods or between the second and fifth periods were not significantly correlated. All other correlations ranged from \((r = 0.24, P < 0.05)\) to \(0.67 (P < 0.001)\). Animals that consumed more feed had greater RFI \(r = 0.39 (P < 0.001)\), however RFI was not significantly related to number of visits or time spent at the feeder \((P > 0.05)\). In a later study, Rauw et al. (2006b) found that pigs that ate faster also ate more \((r = 0.29, P < 0.001)\), grew faster \((r = 0.40, P < 0.001)\), and grew fatter \((r = 0.28, P < 0.001)\), but had no greater or lower residual feed intake \((r = -0.01)\). This discrepancy in the research (Rauw et al., 2006a compared to de Haer et al. 1993) may be an indicator that different populations of pigs have different emphasis on the mechanisms contributing to RFI.

Von Felde et al. (1996) examined 1814 Large White and 1374 Landrace boars. Data for this study were recorded at the testing center of the PIC Improvement Company in Germany between June 1992 and December 1994. The test started when boars were 100 days of age and lasted for a 70-day period. During this testing period, boars were group housed (15 to a pen) and fed ad libitum via an electronic feeder. The authors found a very high genetic correlation between daily feed intake and RFI \((0.97)\). However, the model to estimate RFI did not include a body composition component. They found very low correlations between number of visits and time per visit relative to RFI (estimated between -0.05
Gilbert et al. (2006) examined a line of Large White barrow and gilts or boars divergently selected for RFI, 1450 animals were included in the analysis from for this study. The grow-finish pigs were group housed and fed ad libitum via an electronic feeder. They found a phenotypic correlation between RFI and daily feed intake (0.13), but did not find a correlation between RFI and backfat thickness (-0.03). Cai et al. (2008) examined 168 grow-finish aged purebred Yorkshire, 92 of which were from a line selected for reduced RFI and 76 from a control line. These authors estimated the genetic correlation of RFI with average daily feed intake at 0.52.

**Activity**

In a review paper by Herd et al. (2004) several factors were identified that could contribute to RFI in cattle. These factors were activity, digestion, metabolism both anabolism and catabolism and thermoregulation. Connected to feeding patterns in cattle, Robinson and Oddy (2006) in their review of RFI acknowledged that RFI had a higher correlation with number of visits to the feeder than with number of meals, therefore suggesting that there may be a correlation between RFI and activity. Mice and chickens with different levels of RFI have been shown to display different levels of activity related behaviors. Braastad and Katle (1989) reported that low efficiency (high RFI) White Leghorn laying hens spent more time food-pecking, walking and pacing compared to hens that were divergently bred for high efficiency (low RFI). In this experiment White Leghorn laying hens were
divergently bred for “proportional residual food consumption” (RFI). Twenty of the F3 generation hens with the highest efficiency from the high efficiency line were chosen (out of 276) and 25 of the lowest from the low efficiency hens (out of the 122) were selected for observation. Hens were housed individually in a two-tier conventional cage. The two groups were kept in the same room but separated in order to avoid influencing each other’s behavior. Hens were recorded from 48 to 53 weeks of age. Four hens were recorded on each day, after which the cameras were moved onto another set of four hens, thus each hen was recorded at least twice. The video was examined using a 5-minute instantaneous scan sampling technique. Behavior was assigned to 12 behavior patterns: resting or sleeping, standing, inactive, standing with head movements, food pecking, drinking, grooming, dust bathing, walking, extreme pacing, flight and aggressive behavior. The high-efficiency line was inactive for almost 19.5 ± 2.0 % of the light period compared to the 9.9 ± 0.93% (P < 0.001), for the low-efficiency line. The differences in activity were mainly accounted for by time spent resting and sleeping (high efficiency 14.5 ± 2.2 vs. low efficiency 6.0 ± 0.88%, P = 0.002). The low-efficiency line spent almost twice as much time engaged in walking (2.9 ± 0.29 vs. 1.5 ± 0.06%, P < 0.001) and flight behavior (1.3 ± 0.20 vs. 0.61 ± 0.11%, P = 0.004).

Rauw et al. (2000) compared a high RFI line versus a control line of non-reproductive adult female mice obtained from the 91st generation of a Norwegian mouse selection experiment in a series of tests. The high RFI line came from selection for large litters, which resulted in high RFI. Mice were obtained from 12 litters from each line, with one female pup from the litter being randomly chosen.
The sister pairs were housed together until 10 weeks of age, at which point the mice were housed individually. From age 11 to 15 weeks, the mice were subjected to an open-field procedure, a maze test, a social confrontation test and a runway test. For the open-field test, each mouse was placed in an open-field apparatus for 30 seconds, once in the center and once in the corner. Position of the mouse was recorded every five seconds, and the distance traveled was measured by the cumulative number of squares crossed. The high RFI line of mice crossed more squares (P < 0.05) and went over more squares in the center of the apparatus (high RFI 8.3 vs. control RFI 1.8, P < 0.001). During the maze test, the mice were placed individually into a maze, using a male stimulus mouse, with the test lasting 120 seconds. Each mouse entered the maze once on seven different days. The high RFI line reached the goal area faster on each day (P < 0.05), however the number of mice that did reach the end during the 120 second test was not different (P > 0.05). During the social confrontation test, the mice (which were unfamiliar with each other for all tests) were paired together. Using a 10-second instantaneous scan, the mice were scored for one of nine behaviors (fighting, submissive upright, immobility, social investigation, jumping, upright, sniffing, locomotion and grooming) and a category of miscellaneous. Significant differences were displayed between the control line (8.1 ± 0.8) and the high RFI line (5.5 ± 0.5, P < 0.01) for social investigation. Differences were also observed for locomotion, with the high RFI line engaging in 8.0 ± 0.7 versus the control line at 3.9 ± 0.3 (P < 0.0001). In the runway test, each mouse was twice placed individually on a runway and, latency to reach the 25, 50, 100, 150 and 200 cm marks was recorded. The high RFI line mice had
lower latency times to all distances (P < 0.01). Thus, in general the authors found that mice from the high RFI line engaged in more locomotion activity and were less immobile.

The extent to which selection for reduced RFI is associated with behavior and specifically overall activity in the pig is not known. Limited scientific information is available pertaining to alterations in the behavioral repertoire between low or high RFI pigs in their home pen environment.

Aggression

Differences in aggression related behaviors have been observed in White Leghorn hens, which were divergently bred for differences in efficiency (RFI) (Braastad and Katle, 1989). In this study, 13 of the 24 low efficiency line (high RFI) hens showed aggressive acts during sampling, compared to only 4 of the 18 hens from the high efficiency line (low RFI). Aggression by the low efficiency line was 0.53 ± 0.16 % compared to 0.06 ± 0.03 % by the high efficiency line. The low efficiency line also displayed more agitation behaviors, defined by the authors to include walking, extreme pacing, flight and aggressive behavior (5.1 ± 0.55 vs. 2.2 ± 0.22, %, P < 0.001).

Work by Rauw et al. (2000), as discussed previously in this literature review, also investigated aggressiveness and coping styles of the two lines of mice with known differences in RFI. They reported that during a social confrontation test, mice from the high RFI line investigated the floor and opponent less than mice from
the control RFI line. They also ran faster in a runway test. The authors concluded that this line of mice had developed a more active coping style than the passive style adapted by the control line. Gonyou et al. (1992) examined 160 pigs (barrows and gilts) housed either individually or in groups of five (groups were same sex). The pigs were observed over a 10-week period. They found that group-housed grow-finish pigs spent more time standing (8.35 ± 0.37, %) than their individually housed counterparts (6.95 ± 0.37, %, P = 0.02). They hypothesized that standing may be related to avoidance of other pigs and contribute to a reduction in production. Thus, standing may be a manifestation of different coping mechanisms adapted by swine.

African catfish (*Clarias gariepinus*), which were identified as having either low or high RFI, were examined using pairwise contests to determine differences in aggression by Martins et al. (2008). These authors found that feed efficiency and aggression related behavior seem to be related, but RFI was not correlated to number of bites, number of chases, latency to first bite or time spent chasing (P > 0.05). However, they did find that the fish who initiated the fight had significantly (P = 0.015) lower RFI than the fish who were not the initiators (-0.59 ± 0.29 vs. 0.79 ± 0.44 g kg\(^{-0.8}\) d\(^{-1}\)). The more aggressive fish also had lower RFI values. The individuals with lower RFI initiated the fights and tended to be more aggressive (~0.5 vs. ~0.5; g kg\(^{-0.8}\) d\(^{-1}\), P-value not reported). The authors noted that this is a species that does not establish clear dominate-subordinate relationships, which in addition to many other differences between fish and pigs could be another indicator of caution when attempting to make comparisons between the two species.
Quantification of aggression through live observation or video recordings in animals is expensive and time consuming and so other alternatives to quantify this have been examined, most notably the use of lesion scores in the pig. Turner et al. (2009) noted that, “Selective breeding against aggressiveness ought to be possible if an easily measured indicator trait can be shown to be genetically associated with aggressive behavior”. In their study 1,660 pigs (898 purebred Yorkshire and 762 crossbred Yorkshires x Landrace; 419 boars, 382 barrows and 859 gilts) were utilized. Behavior was recorded for 24 hours upon mixing. Lesion scores were collected 24 hours and 3 weeks post mixing. Counts of lesions were collected on three different areas of the pig: anterior, central and caudal. The authors identified the following aggressive traits to be correlated with growth traits: duration of involvement in reciprocal fighting (0.43 ± 0.04%) and delivery of nonreciprocal aggression (0.31 ± 0.04%). They reported reciprocal fighting to be correlated with the lesion scores on the anterior region of the body 24 hours post mixing. The authors concluded, “A genetic merit index using lesions to the anterior region as one trait and those to the center or rear or both as a second trait should allow selection against animals involved in reciprocal fighting and nonreciprocal aggression”. Furthermore, they also found positive correlations between lesion scores 24 hours post mixing and three weeks after mixing, especially for lesions to the center and rear of the body. In this same work, they estimated heritabilities of 0.31 for nonreciprocal aggression and 0.43 for reciprocal aggression. The number of lesions has long been used as an indicator of the amount of aggression that has occurred post mixing (Turner et al., 2006). Turner et al., 2006 found that lesion
score was significantly correlated to both the frequency of reciprocal fights ($r = 0.397, P < 0.001$) and mean fighting bout length ($r = 0.231, P < 0.05$). Lesion score was not correlated to the proportion of reciprocal fights initiated, won or lost. They also reported a significant negative correlation between the duration spent being bullied and liveweight ($r = -0.218, P < 0.001$). In this work, they examined the possibility that the location of the lesions on different parts of the body may be used as an indicator of reciprocal fighting and when being bullied. For this analysis, they divided the pig into three regions: front (head, neck, shoulder and front legs), middle (flanks and back) and rear (rump, hind legs and tail). The authors found that lesion scores on the front of the pig were correlated to the proportion of time spent in reciprocal fighting ($r = 0.152, P < 0.01$) and that there was a significant relationship between lesion scores on the rear and time spent being bullied ($r = 0.148, P < 0.01$).

**Temperament**

One factor that may affect variation in efficiency is the behavior of the individual animal. Temperament can be considered as the individual animal's reaction to a given set of prescribed circumstances. Some individuals may act agitated and excited when moved through a weigh scale, while others may be calm, walk quietly and show no obvious outward signs of distress (Grandin, 1993). Researchers have been scoring cattle temperament for several years. In 1993 Grandin scored cattle for temperament to see if behavioral agitation was persistent
over time. In this experiment, 53 bulls and 102 steers (Gelbvieh x Simmental X Charolais cross) were restrained in a squeeze chute using a rope halter for blood testing. Each animal was scored on a five-point scale where: 1) calm, no movement, 2) slightly restless, 3) squirming, occasional shaking the squeeze chute, 4) continuous, very vigorous movement and shaking of the squeeze chute and 5) rearing, twisting of the body and struggling violently. If the animal received a score of four or five they were categorized as being behaviorally agitated. Grandin (1993) found that 9% of the bulls and 3% of the steers were behaviorally agitated for each scoring session. Additionally she reported than an additional 8% of the bulls scored three or higher for each session, while 26% rated one or two during each session. Forty-percent of the steers always scored calm. The authors concluded that bulls and steers could be reliably scored using this method and that animal temperaments were somewhat consistent over time. Voisinet et al. (1997a) scored cattle for temperament to determine relationships that may exist between temperament and meat quality attributes, using a scale similar to the previously described scoring system by Grandin (1993). In this study, the researchers examined Braford, Red Brangus and Simbrah mixed sex cattle. Cattle were scored once in a squeeze chute and then tracked through slaughter to examine meat quality attributes. Cattle which had scored excitable (a score of 4) in the chute made up a high proportion of the animals which were borderline dark cutters ($P = 0.01$). The authors note that 7% of the animals that scored calm, were borderline dark cutters compared to 25% of the animals that were scored as excitable. Temperament was also found to be related to tenderness, as measured by Warner-
Bratzler shear force. As temperament increased from calm to excitable, increases in shear force were observed (P < 0.001). The shear force increased from 2.86 ± 0.11 for calm cattle and 3.63 ± 0.19 for cattle with excitable temperaments. Since then, several others have confirmed this relationship, including Burrow and Dillon, 1997, Fell et al., 1999, Petherick et al., 2002; and Vann, 2006. Voisinet et al., (1997b) identified significant differences in temperament between breeds (P < 0.05), indicating a potential genetic component. In this study, several breeds were examined (Braford, Red Brangus, Simbrah, Angus, Simmental x Red Angus, Tarentaise x Angus). The cattle were scored both during their first exposure to the handling facility and after the cattle had 4 to 8 experiences with the system. Cattle were scored while in a non-restraining scale crate. Red Brangus cattle had the highest mean temperament score (3.78 ± 0.22), followed by Braford and Simbrah (3.62 ± 0.15 and 2.89 ± 0.22 respectively). Angus cattle had the lowest mean score of 1.70 ± 0.19, with the other two Bos Taurus cross breeds scoring slightly higher (Simmental x Red Angus 2.36 ± 0.31 and Simmental x Red Angus 1.77 ± 0.07). Perhaps of greater importance, within breed they found that cattle with excitable temperaments had decreased average daily gains, with the calmest temperaments having a 0.19 kilogram per day greater mean average daily gain (P < 0.05). A documented genetic component to temperament justifies an evaluation of how temperament is linked to RFI.

Little research has been conducted on temperament in pigs. In 2008, Holl et al. (2008) attempted to apply the ideas of temperament scoring used in cattle to pigs. In this abstract, they described how they collected temperament score, weight
and three backfat measurements on 1,704 mixed sex Duroc, Large White and Landrace pigs around 156 days of age. They used a scale of 1 to 5; with one indicating a calm pig and five a highly excitable pig, and found that the majority of pigs in their study scored a 1 (56.9%), with each higher score having a lower frequency (2- 28.8%, 3- 9.7%, 4- 4.3% and 5- 0.3%). They also reported a genetic correlation of temperament score with weight at -0.26 and with backfat measurements between -0.16 to -0.20. Estimated heritabilities for temperament score, weight and backfat were 0.30, 0.37 and 0.37 to 0.46 respectively, thus they found the temperament score of the pig was heritable, with a negative genetic correlation with backfat, concluding, “... selection for more docile animals would be expected to result in faster growing fatter pigs.”

The same research group further examined temperament scores of pigs in 2009 in relationship to reproductive and performance traits (Rempel et al., 2009). Although they used the same scale for temperament as was used by Holl et al. (2008), they modified the name to scale activity score. Rempel et al. (2009) further define the scoring system used, indicating a scale of 1 to 5 was implemented in 0.5 increments: 1) remains calm with little or no movement 2) walks forward and backward at a slow pace, 3) continuously moves, 4) continuously moves forward or backward at a rapid pace with vocalization and 5) continuously moves forward or backward at a rapid pace with vocalization and attempts to escape. This time they examined the temperament of the pig relative to reproductive and performance traits. A total of 1,232 of Landrace-Duroc-Yorkshire females were scored at approximately 154 days of age. They found animals that scored three or higher had
a decreased age at puberty (230 ± 2.18 vs. 236.9 ± 1.13 days, P = 0.005). They also found that animals that scored higher were more often diagnosed pregnant 35 days post-breeding (P = 0.026), and had a higher farrowing rate (P = 0.029). Regression analysis indicated that a 1-point increase in scale activity score increased pregnancy and farrowing rates by 3.3% and 3% respectively (P < 0.05). None of the production traits measured (total number born, number born alive, and number weaned by dam) were affected by scale activity. Work has not yet been published to determine the extent to which temperament of the pig during the time of weighing could be used as a predictor of performance, final meat quality attributes, and/or RFI.

**Literature cited**


Feedlot cattle with calm temperaments have higher average daily gains than cattle with excitable temperaments. J. Anim. Sci. 75:892-896.


CHAPTER 3. THE EFFECT OF SELECTION FOR RESIDUAL FEED INTAKE ON GENERAL BEHAVIORAL ACTIVITY AND THE OCCURRENCE OF LESIONS IN YORKSHIRE GILTS

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Abstract

The objectives of this study were to determine the effect of selection for reduced residual feed intake (RFI) on behavior, activity and lesion scores in gilts in their home pen. A total of 192 gilts were used, 96 were from a line that had been selected for low residual feed intake over 5 generations (LRFI) and 96 from a randomly bred control line (CRFI). Gilts were housed in 12 pens (16 gilts/pen; 0.82 m²/gilt) containing 8 gilts from each line in a conventional grow-finish unit. Twelve hours of video footage was collected on the day of placement and then every 4 wk for 3 more observational periods. Video was scored using a 10-min instantaneous scan sampling technique for four postures (standing, lying, sitting and locomotion) and one behavior (at drinker). Categories of active (standing, locomotion and at drinker) and inactive (sitting and lying) were also created. Lesion scores were collected 24-h after behavior collection had begun. The gilt’s body was divided into 4 regions, with each region receiving a score of 0 (0 lesions) to 3 (5+ lesions). All analyses were done using Proc Mixed of SAS. The data were analyzed separately for the day of placement and the subsequent for three rounds. General activity was summarized on a percentage basis by each posture and behavior and subjected to an arcsine square root transformation to help normalize data and stabilize variance. Analysis was performed on each behavior and posture. Lesion scores for each region of the body were analyzed as repeated measures. There were no differences ($P > 0.05$) between genetic lines for all postures and the behavior at drinker on the day of placement. However, over subsequent rounds it was observed
that LRFI gilts spent less ($P = 0.03$) time standing, more time sitting ($P = 0.05$) and were less active ($P = 0.03$) overall. Gilts from the LRFI line had lower ($P < 0.045$) lesion scores on the day after of placement. However, over subsequent rounds there were no ($P > 0.05$) differences between the genetic lines. In conclusion, on the day of placement there were no behavioral differences between genetic lines but LRFI gilts had lower lesion scores. Behavioral differences were observed between genetic lines over subsequent rounds, with LRFI gilts becoming less active, but there were no differences in lesion scores.

**Key words:** behavior, gilts, lesion scores, postures, residual feed intake

**Introduction**

Approximately 34% of differences in feed intake between pigs are not related to growth and backfat (Cai et al., 2008). Although past selection for lean growth has substantially increased feed efficiency in pigs, further increases are limited by differences in feed intake that are unrelated to growth and backfat. These differences in feed intake independent of growth and backfat have been called residual feed intake (RFI) (Koch et al., 1963). Factors that can contribute to RFI include activity, digestion, metabolism (anabolism and catabolism) and thermoregulation (Herd et al., 2004). One factor that may affect differences in RFI may be the behavior of the individual animal. Activity was found to be related to RFI in mice (Rauw et al., 2000), hens (Braastad and Katle, 1989) and cattle (Herd et al.,
2004), with low RFI animals displaying lower levels of activity. Differences in aggression related behaviors have also been observed in hens (Braastad and Katle, 1989). It has been proposed that aggression related activity can be quantified in pigs through the use of lesion scores (Turner et al., 2006). The extent to which selection for reduced RFI is associated with behavior, overall activity and changes in lesion scores in pigs is not known.

At Iowa State University, a line of purebred Yorkshires has been selected for low RFI, alongside a randomly bred control line. After four generations of selection, the low RFI line required 6% less feed for the same amount of growth and backfat (Cai et al., 2008). The objectives of this study were to use this unique resource to determine the extent to which selection for reduced RFI has resulted in correlated responses in behavior, activity and lesion scores.

Materials and methods

Experimental design

The protocol for this experiment was approved by the Iowa State University Institutional Animal Care and Use Committee (12-07-6482-S). The experiment was conducted from April 15 to August 14, 2008. A total of 192 gilts were used. Half of the gilts were from a line that had been selectively bred for low residual feed intake over 5 generations (LRFI) and the other half from a randomly bred control line (CRFI). Development of these lines was described in Cai et al. (2008). The
experimental design for this study was a randomized complete block design, with pen as block and individual pig as the experimental unit.

**Animals**

On the day of placement, gilts were sorted from their home pen by four trained caretakers using sort boards. Gilts were moved to the grow-finish building (320 m) using a height adjustable livestock trailer (Hydraulic Walk-On Livestock Trailer, Roose Manufacturing Company, Pella, IA) in groups of 15 to 18. Gilts were individually moved through a weigh scale (Electronic Weighing Systems, Rite Weigh, Robert E Spencer Enterprises, Ackley, IA) and received an ear tag transponder in the right ear, after which the gilt was moved into her new home pen.

Gilts were moved from the nursery to the grow-finisher unit in 2 starting groups to equalize starting age and weight. All gilts originated from 69 litters. Group 1 began the trial on April 15, 2008. Gilts were allocated to pens 1 through 6 based on their litter and genetic line, distributing litters among the pens and ensuring there were 8 gilts from each genetic line per pen. Genetic line of the individual gilts was kept blind to the technicians throughout the trial and data collection period. Group 1 gilts started the trial at 104 ± 3 d of age and 41.73 ± 5.60 kg body weight. Group 2 was placed on trial 14 d later (April 29, 2008) and started the trial at 92 ± 8 d of age and 37.6 ± 5.8 kg body weight. Group 2 gilts were allocated to pens 7 through 12 using the same methodology as described for group 1. At the end of the trial pigs weighed 79.5 ± 8.9 kg and 67.5 ± 10.7 kg in groups 1 and 2 respectively. Six gilts, 3
from each treatment, were removed due to health issues; therefore 186 gilts completed the trial (LRFI = 93 and CRFI = 93). Results were not affected by removal or inclusion of these 6 gilts in the analyses. Thus, the information from all gilts was included in the analysis up to the point that the gilt was removed from the trial.

**Housing and feeding**

All gilts were housed in a conventional confinement unit located at the Lauren Christian Swine Research Center at the Iowa State University Bilsland Memorial Farm, near Madrid, Iowa. Gilts were housed in 1 room that contained 12 pens, 16 gilts/pen, providing 0.82m$^2$/gilt. Pens were set-up in rows of 6, separated by an aisle (0.83 m wide), so that 6 pens were on the north and 6 pens on the south side of the building. Each pen measured 5.6 m length x 2.3 m width. Pens were separated with steel rod gates. The barn was naturally ventilated with curtain sides providing a natural lighting cycle. Two fluorescent lights, each with one bulb, remained on all the time; this was normal husbandry practice, but also allowed video recording when natural light was not available. During a dark night, the maximum light intensity at ground level directly below the light was 48 lux, with the majority of the room, as established by taking readings at 1 m intervals throughout the room, being less than 5 lux. Each pen contained a 2 nipple-type waterer (Edstrom, Waterford, WI) providing ad libitum access. A Feed Intake Recording Equipment feeder (FIRE®, Osborne Industries, Inc., Osborne, KS) provided ad
libitum access to a standard finishing diet that was formulated to meet or exceed the requirements for growing pigs (NRC, 1998). The FIRE feeder contained a long race leading to the feed trough. This ensured only 1 gilt could consume feed at a time and offered protection to the gilt’s face and sides while she was in the feeder. The FIRE feeder was 1.2 m long and 0.7 m wide. Gilts were checked twice daily at 0800 and 1700 h for health and general maintenance of the facility. These daily checks were maintained during the video and data collection periods, but all other activities in the room and immediate surroundings were kept to a minimal on these days.

**Indoor environmental measurements**

The room was equipped with 4 electronic recording devices (HOBO Pro v2, temp / RH, U23-001, Onset Computer Corporation, Bourne, MA) suspended 1.3 m above the flooring and placed at equal distance throughout the room. The data loggers recorded ambient temperature (°C) and relative humidity (RH, %) every 10 min for the duration of the trial. Environmental parameters were averaged to determine maximum, minimum and average values for the whole trial and for each day that behavior was recorded.
Video collection

Video was collected on the day of placement and then every 4 wk until the end of the trial, for a total of 4 recordings. On the day of gilt placement, video was collected for 12 h after the last gilt was placed into that respective pen (~1100 h and ~1000 h for groups 1 and 2). On the subsequent recording rounds (rounds 1, 2 and 3), video was collected from 0800 h to 2000 h (12 h), which had been previously determined to be the most active times of the day for this housing and feeding system (Sadler et al., 2008). This resulted in 576 h of video (2 groups x 6 pens per group x 4 recordings x 12 h). Twelve color cameras (Panasonic, Model WV-CP484, Matsushita Co. Ltd., Kadoma, Japan) were placed over the 6 pens on the south side of the barn. Gilts were moved from one side of the room to the other every 4 wk so that all gilts could be recorded. Gilts were moved 3 d prior to recording, and were always maintained in the same group after placement and next to the same pen of pigs. Gilts were individually marked with an animal safe paint stick (Prima Tech Retractable Marking Sticks, Prima Tech, NC, U.S.) on their back the day before recording, allowing the behavior of the individual gilt to be collected. Video was collected onto a DVR (RECO, Darim Vision, Pleasanton, CA) at 10 frames per second.
General behavioral activity

General behavioral activity within the home pen was collected by two experienced observers using the Observer software (The Observer, Ver. 5.0.31 Noldus Information Technology, Wageningen, The Netherlands). Training was conducted between the two observers before scoring to insure reliability. Each observer was assigned 6 pens to score throughout the trial, with each scoring all gilts in the assigned pen for the duration of the trial. At the end of all data scoring, one pen was scored by both observers. The observers had over a 98% agreement. Postures and behaviors, which might influence energy usage, were examined. A 10 min instantaneous scan sampling technique was utilized. Individual gilts were classified into 1 of 6 mutually exclusive categories that comprised four postures (locomotion, standing, sitting, and lying down), one behavior (at drinker) and the category of unknown. Behavior definitions were adapted from Hurnik et al. (1985).

**Locomotion** was defined as movement derived from repulsive force from the action of the legs, in which the gilt moved at least half of her body length in the 5 s prior to the scan. **Standing** was defined as maintaining an upright and stationary body position by supporting the body weight on the feet with the legs extended. **Sitting** was defined as a body position in which the posterior of the body trunk is in contact with the ground and supports most of the body weight. **Lying down** included both the sternal and lateral maintenance of a recumbent position. **At drinker** was defined as when the gilt’s mouth was in contact with the water nipple, regardless of posture. A default category of **unknown**, defined as the gilt could not
Lesion scoring

Twenty-four hours after the video collection had begun, lesion scores were collected by 2-trained technicians. Scoring was done in the home pen with one technician scoring all gilts in a pen and the other technician recording the scores. Gilts were identified via their ear tag. Once scored, the gilt received a mark on her back with an animal safe paint stick. Lesions were defined per the PQA Plus definition of skin lesions (NPB, 2007), as “...breaks that completely penetrate the skin, such as bites or other lesions that penetrate through the skin.” A lesion was included in the count if the scab was tightly adhered to it and covered it. If the scab was ready to fall off it was not included. Gilts were scored for all lesions present on the visible portions when standing (e.g., lesions on the underbelly or inside the ears, which are not normally visible on a standing gilt would not have been included). The gilt’s body was divided into 4 regions. **Region 1** was the head, jowl and neck, including the snout and ears. **Region 2** was the withers, shoulders and front legs. **Region 3** consisted of the trunk of the pig, which included the back, chest, loin, abdomen and flank. **Region 4** was the rump, thigh and back legs. Each region received a score of 0 to 3. A 0 indicated there were no lesions present in that region of the gilt. A score of 1 indicated there were 1 or 2 lesions in that region. A
score of 2 indicated 3 or 4 lesions present, and a score of 3 indicated that there were 5 or more lesions present.

**Statistical analysis**

All analyses were done using Proc Mixed of SAS (SAS Inst. Inc., Cary, NC). In all cases, the Kenward-Rodger method was used for computing the denominator degrees of freedom of the test. The data was analyzed separately for the *day of placement* and for *subsequent rounds of recording* (1, 2 and 3). Because the category unknown was often zero and always less than 1% for all measures, it was not included in the analysis and will not be reported on.

**General Activity.** Data for each day of recording were summarized on a percentage basis for each posture (locomotion, standing, sitting and lying) and behavior (at drinker) for each gilt. Additionally, categories of active and inactive were created for analysis. The *active* category included the postures of locomotion and standing and the behavior of drinking. The *inactive* category included the postures of sitting and lying. All percentage measures were transformed using the arcsine square root transformation to normalize the data and stabilize variance. Statistical analysis was performed separately on each behavior and posture. For day of placement, the model included the fixed effect of line, the random effects of litter, group and pen, and age on the day of placement as a covariate. Data from rounds 1, 2 and 3 were analyzed jointly using a repeated measures analysis. For
this purpose, round (1, 2 or 3) and the interaction of round and line were included as additional fixed effects. Covariances between residuals corresponding to the round 1, 2 and 3 observations for each pig were assumed unstructured but constant across pigs. Instead of age, live weight around the time of recording (within three days) was used as a covariate.

Lesions scores. Lesion scores for each region on the individual pig were analyzed as repeated measures with Proc Mixed of SAS. For the day of placement data, the model included the fixed effects of line, region and the interaction of line by region, random effects of litter, group and pen, and live weight around the time of lesion scoring and its interaction with region as covariates. The covariance among residuals corresponding to region 1, 2, 3 and 4 observations for each pig was assumed unstructured but constant across pigs. Data from rounds 1, 2 and 3 were analyzed jointly using a similar model but with round and all interactions between line, round and region added as fixed effects, and round as an additional repeated measure with an autoregressive(1) variance-covariance structure for residuals.
Results

*Indoor environmental measurements*

During the first month the gilts were on trial (04/15/2008 to 05/14/2008), the average temperature-humidity index (THI) in the room was 66 (Table 2.1). Temperature increased slightly throughout the trial, but relative humidity experienced large increases, resulting in an average THI of 75 during the last month. On the day of placement, the average THI was 65 for both groups 1 and 2 and remained fairly constant for each recording period until round 3, for which the THI increased to 80 and 81 for groups 1 and 2, respectively (Table 2.2).

*General activity*

On the day of placement, no differences in behavior were observed between the two lines (Table 2.3). Gilts spent the majority of their time inactive (84.2%). When active, gilts spent the largest percent of their time engaged in standing (11.1%), followed by locomotion (4.2%) and then at drinker (0.5%). During subsequent rounds, differences were observed between the lines. The LRFI line gilts were less active ($P = 0.028$), spent less time standing ($P = 0.027$) and spent more time sitting ($P = 0.051$) than their CRFI counterparts (Table 2.4). Regardless of line, the gilts spent the majority of their time inactive (82%). The round by line interaction was not significant ($P > 0.05$) for all behavior and posture categories.
except sit ($P = 0.016$), showing the LRFI line sat less during round 1 and 3 ($P < 0.05$) but was not significantly different from the CFRI line during round 2 ($P = 0.721$).

When examining the entire population of gilts over the three subsequent rounds, no differences for time sitting or time at the drinker were significant at the 0.05 level (Table 2.5). Gilts engaged in approximately the same amount of locomotion between rounds 1 and 2, but spent less time engaged in locomotion during round 3 ($P < 0.001$). Gilts engaged in less standing during round 3 relative to round 2 ($P < 0.001$) and less lying during round 2 compared to rounds 1 and 3, respectively ($P < 0.001$, Table 2.5).

**Lesion scoring**

On the day after placement, across all regions, the LRFI gilts had lower (2.03 ± 0.12) lesion scores than the CRFI (2.27 ± 0.12) gilts ($P = 0.045$). By examining the line by region interaction ($P < 0.05$), the LRFI gilts had lower scores for all regions than the CRFI gilts (not in table), although this difference was not significant ($P = 0.85$) for region 4. Across lines, regions 1 and 2 had higher ($P < 0.001$) lesion scores than regions 3 and 4 and there was a trend ($P = 0.07$) for region 1 to be higher than region 2 regardless of genetic line (Figure 2.1).

There was no significant difference ($P = 0.66$) in lesion scores between LRFI and CRFI for subsequent rounds (1.84 ± 0.22 vs. 1.80 ± 0.22 lesion score). Across the two lines, lesion scores increased ($P < 0.001$) over rounds 1, 2 and 3 (Figure
This increase with round was observed for each region (Figure 2.3), although region 3 had lower scores than regions 1, 2 and 4. None of the interactions were significant ($P > 0.05$), except the round by region interaction ($P = 0.016$). During all rounds, regions 1 and 2 were not significantly different ($P < 0.10$). During round 1, region 1 was different from region 4 ($P = 0.021$) but during the subsequent rounds they were not significantly different ($P < 0.10$). Region 3 was different ($P < 0.05$) from all other regions for every round.

**Discussion**

Analysis of the first four generations of the selection experiment conducted at ISU for residual feed intake (Cai et al. 2008) indicated that RFI is moderately heritable ($h^2 = 0.29$) and that selection for lower RFI had successfully reduced feed intake by 0.18 kg/d, which represents a 10% reduction. Selection for lower RFI had also slightly reduced growth (~0.03 kg/d) but decreased the amount of feed required for a given amount of growth and backfat by ~1 phenotypic standard deviation and an associated increase in feed efficiency from ~2.65 kg feed required per kg growth to ~2.47 kg. This translates into a 6% reduction in feed costs, and a savings of $3.92 (based off estimated feed cost and consumption; Iowa State University Extension, 2009) per head for the same amount of growth, backfat and pork quality attributes.
Behavioral repertoire differences between high RFI and low RFI animals

Limited scientific information is available pertaining to alterations in the behavioral repertoire between low or high RFI pigs in their home pen environment. However, previous work in cattle (Robinson and Oddy 2004), hens (Braastad and Katle 1989) and mice (Rauw et al. 2000), suggests that differences may exist between animals with different RFI levels. Robinson and Oddy (2004) noted a tendency for cattle that ate fewer meals per day to have lower RFI. In addition, these mixed sex cattle had less subcutaneous fat. Furthermore, these authors reported a genetic correlation between RFI and the amount of time engaged in eating, but eating rate did not seem to be related to RFI. Braastad and Katle (1989) reported that White Leghorn laying hens that had low efficiency (high RFI) spent more time food-pecking, walking and pacing compared to hens that were divergently bred for high efficiency (low RFI). Rauw et al. (2000) subjected a high RFI line versus a control line of non-reproductive adult female mice obtained from a Norwegian mouse selection experiment to a series of tests to determine differences in their coping strategies. The high RFI line came from selection for large litters, which resulted in high RFI. The authors found that mice from the high RFI line engaged in more locomotion activity and scored less time in the behavior category defined as immobile. In the pig, work by de Haer at al, 1993 noted that the eating patterns contributed to RFI and found phenotypic correlations of 0.64, 0.45 and 0.51 for RFI with time spent eating, number of meals per day, and number of visits to the feeder, respectively. The authors concluded that 44% of the phenotypic
variation of RFI in Dutch Landrace and Great Yorkshire pigs was accounted for by the number of visits to the feeders and daily eating time. This was in contrast to Rauw et al. (2006), who concluded that for a population of 200 Duroc barrows, feed intake rate and amount consumed daily did not affect RFI. This discrepancy in the research may be an indicator that different populations of pigs have different mechanisms contributing to RFI. Connected to feeding patterns in these species, Robinson and Oddy (2006) acknowledged that RFI had a higher correlation with number of visits to the feeder than with number of meals, therefore suggesting that there may be a correlation between RFI and activity. In support of this observation, in this study gilts from the LRFI line spent approximately 2% less time engaged in active behaviors in their home pen environment. Regardless of line, gilts spent the majority of their active time standing, and so it is not surprising that the 2% reduction in activity was accompanied by an almost equal decrease in standing. Limited research has indicated that activity levels decrease with age in the pig. In agreement with the current study, finishing pigs decreased standing from 11% to 6% over an 8 wk period (Street and Gonyou 2008). Surprisingly, on the day of placement, when gilts were mixed and establishing a hierarchy (Schmolke et al., 2004), gilts spent only 15% of their time engaged in active behaviors and postures. In part, this may be explained by a very intense period of activity during the initial part of mixing. Although intensity of the activity was not quantified in this study, it was noted that during this time of mixing the gilts engaged in much more run, play and aggressive behaviors. This active period was often followed by long periods of
inactivity, which may have then resulted in the day having a low activity score overall.

Previous work by Rauw et al. (2000) addressed aggressive / copying styles of mice bred to be more efficient and reported that during a social confrontation test, mice from the high RFI line investigated the floor and opponent less than mice from the control RFI line. They also ran faster in a runaway test. The authors concluded that this line of mice had developed a more active coping style than the passive style adapted by the control line. Gonyou et al. (1992) found that group-housed grow-finish pigs spent more time standing than their individually housed counterparts. They hypothesized that standing may be related to avoidance of other pigs and contribute to a reduction in production. In this study, the LRFI line stood less than the CRFI line. This may be an indicator of the general coping mechanisms of the gilts, with the LRFI displaying a more passive style of coping relative to the CRFI line. To date, the coping mechanisms between the two lines used in this study have not been quantified.

The amount of time at the drinker did not change over the trial. A number of factors could contribute to this. Body weight at the time of recording was fitted in the model as a covariate, but removing this did not change the results for significance over the subsequent rounds. As the time at the drinker was scored, rather than actual water consumption, it is possible that when the gilts are smaller they spend more time interacting with the nipple and not actually consuming water. However, a more likely cause would be our ability to detect differences at this level during the
trial. Drinking was always less than 1%, and the lowest difference we detected was a difference of 2 percentage points.

**Lesion scoring**

Aggression related behavioral differences have been observed in laying hens that had been bred for differences in efficiency. Low efficiency (high RFI) White Leghorn laying hens showed more attempts of escape and aggressive related behaviors compared to hens that were divergently bred for high efficiency (low RFI; Braastad and Katle 1989). Aggression was not directly examined in this study, but lesion scores were scored on the individual gilt. Counting or categorizing the number of lesion scores is a methodology that has been proposed as a means to determine pig welfare and in turn to predict the level of aggression that a pig has delivered or sustained. Olesen et al., (1996) and Ayo at al., (1998) reported that fighting between grow-finish pigs will result in wounds and the National Pork Board has suggested that counting and classifying wounds on a pig can be used as a welfare measure on farm (NPB, 2007). Turner et al. (2008) proposed that selection on breeding values of the lesion score could be used to reduce aggression. In 2006 Turner et al. investigated determinates of the accumulation of lesions and found that individual pig weight was the single greatest determinant of lesion scores. In this study, gilt body weight was a significant covariate and was thus included in the model. Our model predicted a one unit increase in lesion score for every 35.2 kg increase in gilt body weight on the day of placement.
Examining the regions of the gilt, we divided the body up slightly different from Turner et al. (2006); essentially, regions 1 and 2 from our study correspond to region 1 from their work. Turner et al. (2006) also found that time spent in reciprocal fighting and being bullied to be determinants of lesion scores. In this same work, they found that engagement in reciprocal fighting resulted in lesions to the front third of the pig (defined as regions 1 and 2 in our work). The recipient of bullying accumulated lesion on the back third of the body (defined as region 4 in our work). In our study, pigs from the LRFI line had lower lesion scores, which may indicate that these pigs are less aggressive. It could be hypothesized that this decreased aggression contributes to the lower RFI value observed in this line. However, the use of regions to identify a bullying and recipient pig is confusing in this study, because the LRFI line scored lower in all regions. Thus further research, most likely through further analysis of the video is needed to determine which gilts were truly more aggressive and bullied, which gilts were the recipient of bully attacks, and which gilts engaged in reciprocal fighting.

Lesion scores were relatively high the day after placement, as would be expected during the time of hierarchy establishment. The score of the entire population was lowest for round 1, which was 28 d after placement, and increased for every subsequent round. This could in theory be do to several factors, such as increased ability to be injured, increased intensity in fighting, resulting in more lesions, or increased frequency of fighting. Again, further research is needed to determine which of these contribute to the increased lesion scores with round. It is surprising that round 3 had the highest score (apart from the day of placement),
given this round also had the lowest activity. Combined with the fact that lesion scores increased with round, this suggests that the gilts spent a greater amount of their active time engaged in aggression related activities in later rounds or aggressive interactions were more intense but these assumptions also need to be further investigated. Interestingly, on the day of placement no differences were observed in postures or behaviors between lines, yet differences were observed between these lines regarding lesion scores. However, the opposite was true during the subsequent rounds, with differences observed in activity between the lines but no differences were observed for lesion scores. This could indicate that activity levels of gilts in their home pen environment may not be strongly correlated to the prevalence of lesion scores.

In conclusion, gilts from the line selected for low RFI had lower lesion scores on the day of placement into the grow-finish environment, and this may be a useful tool to use in a selection program for more efficient gilts. In addition, there were line differences in behavior in the home pen environment, with LRFI gilts being less active over the grow-finish period. Therefore, consideration of lesion score severity on day of placement, combined with the overall behavioral repertoire of the gilt in their home pen may be beneficial for future RFI selection programs and could be added to the list of previously identified factors that may contribute to variation in efficiency of the grow-finish gilt.
Literature cited


Table 3.1
Descriptive statistics for temperature and relative humidity by month in the production room during the length of the trial, April 15 to August 14, 2008.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>One</th>
<th>Two</th>
<th>Three</th>
<th>Four</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air temperature, °C</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum(^1)</td>
<td>12.40</td>
<td>12.98</td>
<td>16.35</td>
<td>17.08</td>
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<tr>
<td>Maximum(^2)</td>
<td>27.80</td>
<td>31.28</td>
<td>32.64</td>
<td>33.15</td>
</tr>
<tr>
<td>Average</td>
<td>20.20</td>
<td>22.85</td>
<td>24.80</td>
<td>25.23</td>
</tr>
<tr>
<td><strong>Relative humidity, %</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum(^3)</td>
<td>26.83</td>
<td>30.50</td>
<td>32.85</td>
<td>48.33</td>
</tr>
<tr>
<td>Maximum(^4)</td>
<td>100.00</td>
<td>97.41</td>
<td>99.83</td>
<td>100.00</td>
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<tr>
<td>Average</td>
<td>60.90</td>
<td>62.77</td>
<td>69.30</td>
<td>79.15</td>
</tr>
</tbody>
</table>

\(^1\) average minimum weekly temperature  
\(^2\) average maximum weekly temperature  
\(^3\) average minimum weekly relative humidity  
\(^4\) average maximum weekly relative humidity  
\(^5\) A month began on the 15 of the calendar month running through the 14 of the proceeding calendar month
### Table 3.2
Descriptive statistics for temperature and relative humidity by behavioral recording day in the production room.

<table>
<thead>
<tr>
<th>Round</th>
<th>Day of placement</th>
<th>One</th>
<th>Two</th>
<th>Three</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1</td>
<td>Group 2</td>
<td>Group 1</td>
<td>Group 2</td>
</tr>
<tr>
<td><strong>Parameter</strong></td>
<td><strong>Air temperature, °C</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>18.71</td>
<td>16.61</td>
<td>19.89</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>21.39</td>
<td>20.86</td>
<td>25.69</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>20.64</td>
<td>19.67</td>
<td>23.17</td>
</tr>
<tr>
<td><strong>Relative humidity, %</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>30.62</td>
<td>42.79</td>
<td>27.76</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>42.64</td>
<td>76.55</td>
<td>61.93</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>35.67</td>
<td>55.73</td>
<td>37.67</td>
</tr>
</tbody>
</table>

1 Day of placement temperature were recorded are from to ~1100 - 2300 h for group 1 and ~1000 – 2200 h for group 2. For all subsequent rounds, temperature values were recorded from 0800 – 2000 h.
2 Group 1 April 15, 2008
3 Group 2 April 29, 2008
4 Average minimum hourly temperature
5 Average maximum hourly temperature
6 Average minimum hourly relative humidity
7 Average maximum hourly relative humidity
Table 3.3
Least square means ± SE for grow-finish gilt postures and behavior at drinker in their home pen when comparing gilts from a line selected for low residual feed intake (LRFI) and a control line (CRFI) on the day of placement in April, 2008. Behaviors adapted from Hurnik et al., 1985.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LRFI</th>
<th>SE</th>
<th>CRFI</th>
<th>SE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Locomotion</td>
<td>4.25</td>
<td>1.59</td>
<td>4.00</td>
<td>1.59</td>
<td>0.728</td>
</tr>
<tr>
<td>Standing</td>
<td>10.30</td>
<td>2.94</td>
<td>11.90</td>
<td>2.94</td>
<td>0.113</td>
</tr>
<tr>
<td>Sitting</td>
<td>2.25</td>
<td>0.37</td>
<td>1.98</td>
<td>0.37</td>
<td>0.503</td>
</tr>
<tr>
<td>Lying</td>
<td>82.70</td>
<td>5.02</td>
<td>81.60</td>
<td>5.02</td>
<td>0.342</td>
</tr>
<tr>
<td>Active</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.09</td>
<td>5.09</td>
<td>16.38</td>
<td>5.09</td>
<td>0.285</td>
<td></td>
</tr>
<tr>
<td>Inactive</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>84.88</td>
<td>5.02</td>
<td>83.54</td>
<td>5.03</td>
<td>0.270</td>
<td></td>
</tr>
</tbody>
</table>

1 Genetic line; low residual feed intake (LRFI n = 96) which had been selectively bred for low residual feed intake over 5 generations and control residual feed intake (CRFI n = 96) gilts from a randomly bred line
2 Postures and behavior were observed using a 10 min instantaneous scan sample technique
3 Active is the combination of postures locomotion and standing and the behavior at drinker
4 Inactive is the combination of the postures sitting and lying
5 Established using transformed data
Table 3. 4
Least square means ± SE for grow-finish gilt postures and behavior at drinker in their home pen when comparing gilts from a line selected for low residual feed intake (LRFI) and a control (CRFI) line for the subsequent rounds in May 2008 to August 2008. Behaviors adapted from Hurnik et al., (1995).

<table>
<thead>
<tr>
<th>Genetic Line 1</th>
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<tr>
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<tr>
<td>At drinker</td>
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1Genetic line; low residual feed intake (LRFI n = 96) which had been selectively bred for low residual feed intake over 5 generations and control residual feed intake (CRFI n = 96) gilts from a randomly bred line
2Postures and behavior were observed using a 10 min instantaneous scan sample technique
3Active is the combination of postures locomotion and standing and the behavior at drinker
4Inactive is the combination of the postures sitting and lying
5Established using transformed data
Table 3.5


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<th>Parameter(^2)</th>
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<td>20.13(^b)</td>
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<tr>
<td>At drinker</td>
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\(^1\)Genetic lines low residual feed intake and control residual feed intake (n = 192)
\(^2\)Postures and behavior were observed using a 10 min instantaneous scan sample technique
\(^3\)Active is the combination of postures locomotion and standing and the behavior at drinker
\(^4\)Inactive is the combination of the postures sitting and lying
\(^5\)Established using transformed data
\(^a,b,c\)Superscripts indicate differences within a row at \(P\)-value <0.001, values were established using transformed data
**Figure 3. 1**
Lesion score least square means for all grow-finish gilts\(^1\) on the day of placement.

![Graph showing lesion scores for different regions.](image)

- **Region 1** was the head, jowl and neck, including the snout and ears
- **Region 2** was the withers, shoulders and front legs
- **Region 3** was the trunk of the pig, which included the back, chest, loin, abdomen and flank
- **Region 4** was the rump, thigh and back legs

\(^{a,b}\) Superscripts indicate differences within a row differ at \(P\)-value < 0.05

\(^1\) Genetic lines low residual feed intake and control residual feed intake (n = 192)
Figure 3.2
Lesion score least square means for all grow-finish gilts\(^1\) during the subsequent rounds.

\[\begin{align*}
\text{Round 1} &= 30 \text{ days after the day of placement} \\
\text{Round 2} &= 28 \text{ days after Round 1} \\
\text{Round 3} &= 28 \text{ days after Round 2} \\
\end{align*}\]

\(^{a,b,c}\) Superscripts indicate differences within a row differ at \(P\text{-value} < 0.05\)

\(^1\) Genetic lines low residual feed intake and control residual feed intake (\(n = 192\))
**Figure 3.3**
Lesion score least square means for all grow-finish gilts\(^1\) during the subsequent rounds by region

Region 1 was the head, jowl and neck, including the snout and ears
Region 2 was the withers, shoulders and front legs
Region 3 was the trunk of the pig, which included the back, chest, loin, abdomen and flank
Region 4 was the rump, thigh and back legs

\(^{a,b}\) Superscripts indicate differences within a row differ at \(P\)-value < 0.05
\(^1\) Genetic lines low residual feed intake and control residual feed intake (\(n = 192\))
CHAPTER 4. THE EFFECT OF SELECTION FOR RESIDUAL FEED INTAKE ON SCALE ACTIVITY AND EXIT SCORE IN YORKSHIRE GILTS

A paper to be submitted to the journal Animal

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Abstract

A total of 192 grow-finish purebred Yorkshire gilts were used for this trial. Ninety-six were from a line that had been selectively bred for low residual feed intake over five generations (LRFI) and 96 from a randomly selected bred control line (CRFI). The objectives of this study was to determine the effect of selection for reduced RFI on scale activity and exit scores and to determine if gilts become habituated to the process of weighing. Gilts were weighed every two weeks for a maximum of eight scores per gilt. Gilts were scored while on the weigh scale for activity using a whole number scale of one to five (1 = calm, minimal movement; 5 = continuous rapid movement and an escape attempt). Scores were taken at two time points T=0 (immediately upon the back gate closing on the weigh scale) and T=15 (15 seconds after). Gilts were also scored for willingness to exit the scale (using a whole number scale of 1 to 3; no encouragement needed to encouragement needed). Statistical differences were found in all rounds between genetic lines except rounds two, four and five. When comparing both genetic lines over all rounds gilt scale activity scores decreased. The LRFI line began with a lower scale activity score, but did not experience as great of a drop in their score as the CRFI gilts. The CRFI gilts scored lower by end of the round compared to the LRFI gilts. For activity on the weigh scale for the entire population of gilts the differences during round one between T=0 and T=15 was 20% higher on the 5 point scale. By round eight this had dropped down to a 3% difference. For exit score in rounds 5 and 7 the LRFI line scored lower than the CRFI line and there was a trend for the
LRFI line to score lower in round six. Over the entire population of gilts, the mean score increased slowly throughout the trial. In conclusion, selection for lower residual feed intake in purebred Yorkshires has a complex effect on scale activity score, and can be added to the list of already described traits in pigs as a factor which relates to selection for lower RFI.

**Key words:**
Gilt, Residual Feed Intake, Scale Activity Scoring

**Implications**
Differences were observed between genetic lines, and selection for lower RFI did not adversely affect behavior. Improvement in RFI could be considered in a breeding selection program.

**Introduction**
Approximately 34% of differences in feed intake between pigs are not related to growth and composition but result from variation in efficiency of the individual pig (Cai et al., 2008). The factors that contribute to variation in feed efficiency include activity, digestion, metabolism (anabolism and catabolism) and thermoregulation (Herd et al., 2004). Previous demonstrations show that selection for lean growth has substantially increased feed efficiency in pigs; further increases maybe limited
by differences in feed intake that are unrelated to growth and backfat. Feed intake variation that is independent of growth and composition has been referred as residual feed intake (RFI; Koch, et al, 1963). One additional factor that may affect variation in efficiency is the behavior of the individual pig.

Over the past decade, a line of purebred Yorkshires has been selected for low RFI at Iowa State University, alongside a randomly selected control line. After four generations of selection, the low RFI line required 6% less feed for the same amount of growth and backfat (Cai et al, 2008).

Purebred Yorkshire gilts (n = 192) were used for this trial. Ninety-six gilts were from the line that had been selectively bred for low residual feed intake over five generations (LRFI) and 96 gilts that had been randomly selected for five generations to serve as a control line (CRFI). Gilts averaged 98 d old when placed on trial and were housed in a conventional grow-finish barn. The gilts were scored while on the weigh scale for activity using a whole number scale of one (calm, minimal movement) to five (continuous rapid movement and an escape attempt). Gilts were weighed every two weeks for a maximum of eight scores per gilt. Gilts during each weight collection period were scored for the rate at which they exited the scale (one to three; one = freely exited, three = encouragement needed for any exiting).

The extent to which selection for reduced RFI affects swine temperament is unknown. Therefore, the objectives of this study were to determine how selection for reduced RFI may correlate with individual gilt behavioral response to scale
activity and exit score and to determine if gilts will become habituated to the process of weighing.

Materials and methods

Experimental design

The protocol for this study was approved by the Iowa State University Institutional Animal Care and Use Committee (12-07-6482-S). This experiment was conducted from April 15, 2008 to August 14, 2008. Animals came from two lines of Yorkshire pigs that were created at Iowa State University. One line has been selected for decreased residual feed intake (LRFI) and the other line has been randomly selected (CRFI). Breeding selection for the development of these has been previously described by Cai et al., (2008). A total of 192 gilts were used, 96 LRFI gilts and 96 CRFI gilts. The experimental design for this study was a randomized complete block design, with pen as block. The experimental unit was the individual gilt.

Animals

On the day of placement, four trained caretakers using sort boards sorted gilts from their home pen. The gilts were moved (320 m) to the conventional grow-finish barn using a height adjustable livestock trailer (Hydraulic Walk-On Livestock
Trailer, Roose Manufacturing Company, Pella, IA) in groups of 15 to 18 gilts. Gilts were individually moved through a weigh scale where they received an ear tag transponder in the right ear. This tag included a visible number that was used to identify the gilt throughout the trial. The gilt was then moved into her new home pen. Gilts were not scored on this day.

Gilts originated from 69 different litters and were placed on trial as two starting groups, this was done to help equalize starting age and weight. Group one began the trial on April 15, 2008. Gilts were allocated to pens one through six based on their litter and genetic line, distributing litters among the pens and ensuring there were eight gilts from each genetic line per pen, for a total of 16 gilts per pen. These gilts were on average 104 ± 3 d old at the start of the trial and weighed 41.73 ± 5.60 kg. Group two gilts were placed on trial 14 d later and were allocated to pens seven through 12 in a similar fashion. Group two gilts started the trial at 92 ± 8 d of age and weighed 37.6 ± 5.8 kg. Six gilts, three from each treatment, were removed from this trial due to health issues; therefore 186 gilts completed the trial (LRFI = 93 and CRFI = 93). Data from these six gilts were included in the analysis up to the point they were removed from the trial, as their exclusion did not affect results.

**Housing and feeding**

Pigs were housed in a conventional grow-finish barn at the Iowa State University Lauren Christian Swine Research Center in one room. The room
consisted of 12 pens, each with fully slatted concrete flooring. Each pen was 5.6 m length x 2.3 m width (0.82 m²/gilt) and pens were separated with steel rod gates. The unit was naturally ventilated with curtain sides providing natural lighting cycles. Two florescent light fixtures, each with one bulb, were kept on continuously. Each pen contained a two nipple-type waterer, (Edstrom, Waterford, WI) providing ad libitum access. A Feed Intake Recording Equipment feeder (FIRE®, Osborne Industries, Inc., Osborne, KS) provided ad libitum access to a standard finishing diet that was formulated to meet or exceed the nutritional requirements for growing pigs (NRC, 1998).

Indoor environmental measurements

The room was equipped with four electronic recording devices (HOBO; Hobo Pro series, Janesville, WI). The electronic recording devices were affixed 1.3 m above the floor. Ambient temperature (°C) and relative humidity (RH, %) were recorded in 10-min intervals for the entire trial. Environmental parameters were averaged to determine maximum, minimum and average values for each event of this trial.

Behavior scoring

One week after placement, gilts were moved from their home pen to a central location to be weighed and scored for scale activity. Starting at 0700 h, gilts
were moved as a whole pen with sort boards (0.9 x 1.2 m) by two trained persons that had experience moving gilts from their home pen to this central holding area. The pen closest to the central holding area was a distance of 4.5 m, while the pen farthest away was 18.3 m. The holding area was 5.93 m² and thus provided a space allowance of 0.38 m² per pig. This area had the same flooring as in the home pen and alleyway. Curtains were not in this area and thus opening doors located on the north and south side of the area provided ventilation. Lighting was similar to the home pen area, with fluorescent lights.

Scale activity scoring was conducted every two wks until the first gilts completed the trial, at which point average gilt weight was 104 kg. Scale activity scores were collected over nine sessions; with only group one being scored during session one and only group two being scored during sessions eight and nine respectively due to: (1) group one started at a heavier weight and (2) groups one and two went on trial on two separate dates. Once in the holding area, each gilt was individually moved onto the weigh scale (Electronic Weighing Systems, Rite Weigh, Robert E Spencer Enterprises, Ackley, IA). The scale was a freestanding self-sustained flow through unit. The weigh scale was of steel construction with waved fiberglass sides and metal woven flooring with rebar spaced 0.30 m for added protection against slipping. The gates, located on both the entrance and exit of the scale, were 1.9 cm angle iron spaced 10.2 cm on center. The inside dimensions of the weigh scale were 0.41 m wide by 1.24 m long by 0.76 m tall. Once all gilts from a pen were scored, they were moved back to their home pen. Scoring of all pens was completed by approximately 1200 h. Each gilt received a scale activity score by
two observers, was weighed (data not reported) and then allocated a scale exit score by one observer. Individual gilt scale activity was determined and recorded while she was on the weigh scale. The individual gilt was identified by her ear tag number and therefore observers were blind to genetic line of the gilt. Activity score while in the scale was on a subjective scale of one to five that was slightly modified from the scale activity score described by Rempel et al., (2009), including the use of only whole numbers (Table 3.1). Each observer scored the gilt immediately upon entering the scale and the back gate being closed (T=0) and 15 seconds after the gate closed (T=15).

Scale exit score was collected when the gilt exited the weigh scale. The gilt was scored by one observer using a scale of one to three: with one indicating the gilt exited the scale on her own, a two indicating the gilt exited part of the way on her own and needed encouragement to finish exiting the scale, and a score of three indicating the gilt needed encouragement to exit the scale.

*Statistical analysis*

All analyses were done using Proc Mixed of SAS (SAS Inst. Inc., Cary, NC). In all cases, the Kenward-Rodger method was used to compute the denominator degrees of freedom. For analysis purposes, gilts were scored on seven or eight rounds (group one and two respectively), where round is number of times a gilt was exposed to the process. Round is in contrast to session and is defined as the number of days the technicians collected data. Therefore during the first session
only group one gilts were scored. In the second session group one gilts were scored for their second round, while group two gilts were scored for their first round.

The scores of the two technicians were averaged to create a single score at each time (T=0, T=15) for each pig and used for analysis. Data was analyzed as a repeated measurers using Proc Mixed. The model included the fixed effects of line, round, time and all interactions. Random effects of litter, group and pen were included, along with the repeated measures of round (one through eight) and time (T=0 and T=15). Weight at the time of scoring was included as a covariate but was not found to be significant and was removed from the model. A variance-covariance structure between rounds was assumed unstructured but constant. An autoregressive(1) structure was applied to the covariance of the residuals of time. 

*P*-values, when appropriate, are presented both raw and with a Bonferroni adjustment. *P*-values, when adjusted using Bonferroni, are indicated as such.

The exit scores were analyzed as repeated measures, with a model similar to scale activity scores. This model included the fixed effects of line, round and line by round interactions. A covariate of the age of the gilt at the time of placement was used. The random effects of litter, group and pen were included in this model. A covariate-structure of autoregressive(1) was applied. *P*-values when appropriate are presented both raw and with a Bonferroni adjustment. *P*-values when, adjusted using Bonferroni, are indicated as such.
Results and discussion

Indoor environmental measurements

Over the four months of the trial, average temperature ranged from 20.2 °C for month one up to 25.2 °C for month four. Average relative humidity ranged 60.9% for month one up to 79.5% for month four (Table 3.2). Over the scale activity rounds, average temperature ranged from 14.5 °C for round four up to 27.9 °C on round seven. Average relative humidity ranged from 55% for round two up to 90.7% during round eight respectively (Table 3.3).

Scale activity scoring

Temperament can be considered as the individual animal's reaction to a given set of prescribed circumstances. Some individuals may act agitated and excited when moved through a weigh scale, while others may be calm, walk quietly and show no obvious outward signs of distress (Grandin, 1993). Previous work has indentified a relationship between cattle temperament and final meat quality attributes (Burrow and Dillon 1997; Fell et al., 1999; Petherick et al., 2002; Vann 2006). Further more, Voisinet et al. (1997) indentified differences in temperament between breeds, indicating a potential genetic component. Perhaps of greater importance, within breed they found that cattle with excitable temperaments had
decreased average daily gains. A documented genetic component to temperament justifies an evaluation of how temperament is linked to RFI.

**Genetic line**

Little research has been conducted in the pig regarding their temperament during the weighing and handling process. In addition, work has not yet been published to determine the extent to which temperament of the pig during the time of weighing could be used as a predictor of performance and/or final meat quality attributes. This study examined if selection for lower residual feed intake altered gilt temperament during the weighing and handling process compared to control gilts. Holl et al. (2008) found that scale activity score of the pig was heritable, with a negative genetic correlation to backfat concluding, “... selection for more docile animals would be expected to result in faster growing fatter pigs.” In the selection lines used for this study, feed efficiency differences are observed between lines (Cai et al., 2008).

Across all rounds (one through eight) and times (T=0 and T=15) there were no \( P = 0.14 \) significant differences between LRFI and CRFI gilts for scale activity (1.89 ± 0.11 vs. 1.81 ± 0.11 scale activity). However, differences were observed when comparing the lines in individual rounds over both time points. During round one, the LRFI line had a lower mean temperament score then the CRFI line (2.31 vs. 2.65; \( P = 0.001 \)). For all other rounds, if a Bonferroni adjustment is applied, there were no significant line effects \( P > 0.05 \). However, if left unadjusted
statistical differences between lines were found in all rounds, except two, four and five \( (P < 0.05) \) (Table 3.4). For both genetic lines, temperament scores decreased from round one to round eight, but the LRFI line did not experience as large a drop in mean score as the CRFI line (Table 3.4). Thus as noted, the LRFI line scored lower than the CRFI line in the first round, but by the last round, this relationship had switched. Throughout the trial, gilts from both lines were considered calm; by round four, both lines had a mean score below two, with a score of one and two indicating a calm pig.

**Entire population of gilts over all rounds**

Temperament scores were assigned over several rounds and thus it was possible to determine pig response to the process of being weighed. Many animals find novelty to be a stressful event (Grandin, 1997). If an animal finds the event to be aversive, the level of displayed agitation should increase (Grandin et al., 1986; Poscoe 1986) with each subsequent exposure to the process until a threshold is reached. However if the stimulus is not extremely aversive, the displayed level of agitation should decrease. This was documented in bongo (Phillips et al. 1998), an easily stressed animal relative to the domestic pig. Thus, by examining the gilts over several time periods, we can get an idea of how aversive the gilts find the process, or if they are able to habituate to it. Waynert et al. (1999) noted that cattle become acclimated to the sounds of people yelling and metal clanking on metal. The common husbandry practice of weighing the gilts would be considered
relatively unobtrusive compared to other husbandry practices. Contact with the gilts was minimal and the gilts were allowed to explore outside of their home pen.

Examining the time by line interaction there were no differences ($P > 0.05$) between genetic lines over all rounds or within rounds at time zero ($T=0$) versus 15 seconds later ($T=15$) (data not shown). During round one, the mean scale activity score for all gilts sampled was $2.48 \pm 0.12$. The scale activity score dropped in each successive round reaching $1.51 \pm 0.12$ in round five at which point it stabilized and did not change during the remaining rounds (Figure 3.1).

Over all rounds and for both lines $T=0$ was $1.68 \pm 0.11$ which was significantly lower than $T=15$ at $2.02 \pm 0.11$ ($P < 0.001$), indicating that the agitation of the gilt or the perceived agitation by the technician of the gilt increased with length of time in the scale. The time by round interaction was significant for each round ($P < 0.001$), with the $T=0$ score always being lower than $T=15$ (table 4). During round one the mean score for $T=0$ was 1.98 and for $T=15$ 2.98, a full 20% higher on the 5 point scale. In round eight this difference had dropped down to a mean $T=0$ score of 1.49 and $T=15$ score of 1.64, a 3% difference.

**Scale exit score**

Using a Bonferroni adjustment there was a difference ($P = 0.026$) between genetic in the seventh round. Without the Bonferonni adjustment in rounds 5 and 7, the LRFI line scored lower ($P < 0.05$) than the CRFI line and there was a trend ($P = 0.073$) for the LRFI line to score lower in round six (Table 3.5). Over the entire
population of gilts, the mean score during round one was 1.14 (one= freely exit). This score then increased slowly through the trial, with a score of 1.89 during round seven (Figure 3.2). This suggests that the gilts were acclimated to the process, becoming calmer as the number of times exposed to the process increased.

Conclusion

Selection for lower residual feed intake in purebred Yorkshires has a related effect on scale activity score but this relationship is complicated and thus warrants further research. Gilts do become habituated to the process of weighing and as such do not seem to find this process highly aversive.

Acknowledgements

This work was supported by the National Pork Board Project Number 07-161 and the Hatch Funds from the Department of Animal Science, Iowa State University. The authors thank Allison Meiszberg, Jill Garvey, Weiguo Cai, John Newton and the staff at the Lauren Christian Swine Research Center and Man-Yu for technical assistance.


http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=2387

24. accessed 08-15-09


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</tr>
<tr>
<td>2</td>
<td>Calm movement, including the sow walking forward and backward at a slow pace</td>
</tr>
<tr>
<td>3</td>
<td>Continuous fast movement, including quickly walking forward and backward</td>
</tr>
<tr>
<td>4</td>
<td>Continuous rapid movement and vocalizing</td>
</tr>
<tr>
<td>5</td>
<td>Continuous rapid movement and an escape attempt</td>
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Table 4.2
Descriptive statistics for temperature and relative humidity in the production room by month during the length of the trial, April 15 – August 14, 2008

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<td>24.8</td>
<td>25.2</td>
</tr>
</tbody>
</table>

| Relative humidity, %    |       |       |       |       |
| Minimum<sup>3</sup>     | 26.8  | 30.5  | 32.9  | 48.3  |
| Maximum<sup>4</sup>     | 100.0 | 97.4  | 98.9  | 99.8  |
| Average                 | 60.9  | 62.8  | 69.3  | 79.2  |

<sup>1</sup>Average minimum weekly temperature
<sup>2</sup>Average maximum weekly temperature
<sup>3</sup>Average minimum weekly temperature
<sup>4</sup>Average maximum weekly temperature
<sup>5</sup>A month began at the beginning for the trial running from the 15 of the calendar month to the 14 of the proceeding calendar month
Table 4.3
Descriptive statistics for temperature and relative humidity on data collection days.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1&lt;sup&gt;a,2&lt;/sup&gt;</th>
<th>2&lt;sup&gt;3&lt;/sup&gt;</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8&lt;sup&gt;4&lt;/sup&gt;</th>
<th>9&lt;sup&gt;4&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air temperature, °C</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>16.1</td>
<td>18.7</td>
<td>18.7</td>
<td>11.0</td>
<td>19.0</td>
<td>19.4</td>
<td>24.4</td>
<td>21.1</td>
<td>22.6</td>
</tr>
<tr>
<td>Maximum</td>
<td>22.5</td>
<td>28.5</td>
<td>22.1</td>
<td>17.1</td>
<td>26.8</td>
<td>26.5</td>
<td>30.8</td>
<td>24.7</td>
<td>27.9</td>
</tr>
<tr>
<td>Average</td>
<td>19.4</td>
<td>24.1</td>
<td>20.5</td>
<td>14.5</td>
<td>23.2</td>
<td>23.7</td>
<td>27.9</td>
<td>23.0</td>
<td>25.2</td>
</tr>
<tr>
<td><strong>Relative humidity, %</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>63.3</td>
<td>40.2</td>
<td>52.0</td>
<td>70.9</td>
<td>70.3</td>
<td>44.7</td>
<td>66.9</td>
<td>81.2</td>
<td>70.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>85.6</td>
<td>72.5</td>
<td>65.8</td>
<td>85.8</td>
<td>99.9</td>
<td>85.6</td>
<td>95.1</td>
<td>98.8</td>
<td>99.8</td>
</tr>
<tr>
<td>Average</td>
<td>76.3</td>
<td>55.1</td>
<td>59.0</td>
<td>77.1</td>
<td>88.7</td>
<td>60.4</td>
<td>85.5</td>
<td>90.8</td>
<td>84.1</td>
</tr>
</tbody>
</table>

1<sup>only group one gilts were scored during this session</sup>
2<sup>round one data collected for group one gilts following in sequence</sup>
3<sup>round two data collected for group 1 gilts and round one data collected for group 2 gilts following in sequence</sup>
4<sup>only group 2 gilts were scored during these sessions</sup>
5<sup>temperature data is from 0700 h until 1200 h during the day of data collection</sup>
Table 4.4
Least square means and standard errors of scale activity score by line and time of score

<table>
<thead>
<tr>
<th>Round</th>
<th>Parameter</th>
<th>Parameter</th>
<th>( P)-value</th>
<th>Adjusted ( P)-value (^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LRFI(^{4,7})</td>
<td>CRFI(^{5,7})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2.31</td>
<td>2.65</td>
<td>&lt;0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>2</td>
<td>2.33</td>
<td>2.44</td>
<td>0.196</td>
<td>1.000</td>
</tr>
<tr>
<td>3</td>
<td>2.21</td>
<td>2.01</td>
<td>0.031</td>
<td>0.244</td>
</tr>
<tr>
<td>4</td>
<td>1.73</td>
<td>1.65</td>
<td>0.403</td>
<td>1.000</td>
</tr>
<tr>
<td>5</td>
<td>1.58</td>
<td>1.44</td>
<td>0.119</td>
<td>0.955</td>
</tr>
<tr>
<td>6</td>
<td>1.65</td>
<td>1.47</td>
<td>0.040</td>
<td>0.321</td>
</tr>
<tr>
<td>7</td>
<td>1.60</td>
<td>1.41</td>
<td>0.046</td>
<td>0.370</td>
</tr>
<tr>
<td>8(^3)</td>
<td>1.69</td>
<td>1.44</td>
<td>0.013</td>
<td>0.108</td>
</tr>
<tr>
<td></td>
<td>T=0(^{6,8})</td>
<td>T=15(^{6,8})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.98</td>
<td>2.98</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>2</td>
<td>2.14</td>
<td>2.62</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>3</td>
<td>1.97</td>
<td>2.25</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>4</td>
<td>1.56</td>
<td>1.82</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>5</td>
<td>1.45</td>
<td>1.56</td>
<td>0.007</td>
<td>0.056</td>
</tr>
<tr>
<td>6</td>
<td>1.42</td>
<td>1.69</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>7</td>
<td>1.43</td>
<td>1.58</td>
<td>&lt;0.001</td>
<td>0.003</td>
</tr>
<tr>
<td>8(^3)</td>
<td>1.49</td>
<td>1.64</td>
<td>0.001</td>
<td>0.009</td>
</tr>
</tbody>
</table>

\(^1\)Bonferroni adjustment of \( P\)-value
\(^2\)Analysis only includes data from Group 1 pigs
\(^3\)Analysis only included data from Group 2 pigs
\(^4\)Low residual feed intake line (n = 96)
\(^5\)Control residual feed intake line (n = 96)
\(^6\)Low residual feed intake line and control residual feed intake line (n = 192)
\(^7\)SE between lines for all rounds was 0.13
\(^8\)SE between times was 0.12
Figure 4.1
Least square means estimate of scale activity score by round over the entire population of gilts\(^1\). Superscripts indicate differences at \(P\)-value < 0.05

\(^1\)Low residual feed intake gilts and control residual feed intake gilts (\(n = 192\)). Scale activity scores: 1) Calm pig, little or no movement, 2) Calm movement, including the sow walking forward and backward at a slow pace, 3) Continuous fast movement, including quickly walking forward and backward, 4) Continuous rapid movement and vocalizing and 5) Continuous rapid movement and an escape attempt
Figure 4. 2
Least square means estimate of scale exit score over the entire population of gilts\(^1\). Superscripts indicate differences at \(P\)-value < 0.05

\(^1\)Low residual feed intake gilts and control residual feed intake gilts (n = 192).
Exit score: 1) gilt exited the scale on her own, 2 gilt exited part of the way on her own and needed encouragement to finish exiting the scale, 3 the gilt needed encouragement to exit the scale.
Table 4. 5  
Least square means and standard error of exit score of gilts by line

<table>
<thead>
<tr>
<th>Round</th>
<th>LRFI $^4$</th>
<th>SE</th>
<th>CRFI $^5$</th>
<th>SE</th>
<th>$P$-value</th>
<th>Adjusted $P$-value $^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1$^2$</td>
<td>1.17</td>
<td>0.08</td>
<td>1.11</td>
<td>0.08</td>
<td>0.610</td>
<td>1.000</td>
</tr>
<tr>
<td>2</td>
<td>1.03</td>
<td>0.08</td>
<td>1.04</td>
<td>0.08</td>
<td>0.951</td>
<td>1.000</td>
</tr>
<tr>
<td>3</td>
<td>1.30</td>
<td>0.08</td>
<td>1.27</td>
<td>0.08</td>
<td>0.822</td>
<td>1.000</td>
</tr>
<tr>
<td>4</td>
<td>1.54</td>
<td>0.08</td>
<td>1.43</td>
<td>0.08</td>
<td>0.322</td>
<td>1.000</td>
</tr>
<tr>
<td>5</td>
<td>1.35</td>
<td>0.08</td>
<td>1.58</td>
<td>0.08</td>
<td>0.037</td>
<td>0.299</td>
</tr>
<tr>
<td>6</td>
<td>1.49</td>
<td>0.08</td>
<td>1.69</td>
<td>0.08</td>
<td>0.073</td>
<td>0.585</td>
</tr>
<tr>
<td>7$^3$</td>
<td>1.72</td>
<td>0.08</td>
<td>2.05</td>
<td>0.08</td>
<td>0.003</td>
<td>0.026</td>
</tr>
<tr>
<td>8$^3$</td>
<td>1.64</td>
<td>0.08</td>
<td>1.84</td>
<td>0.09</td>
<td>0.111</td>
<td>0.868</td>
</tr>
</tbody>
</table>

$^1$Bonferroni adjustment of $P$-value  
$^2$Analysis only includes data from Group 1 pigs  
$^3$Analysis only included data from Group 2 pigs  
$^4$Low residual feed intake line (n = 96)  
$^5$Control residual feed intake line (n = 96)
CHAPTER 5. GENERAL SUMMARY

This research has demonstrated that a line of purebred Yorkshire gilts, developed for low residual feed intake (LRFI), exhibited behavioral and temperament differences when compared to a control line (CRFI). The research also indicates further studies are warranted regarding several areas related to both RFI and general perceptions regarding the grow-finish pig. On the day of placement, no differences were observed between genetic lines regarding their general behavioral activity. Over the trial, the LRFI gilts stood less, sat more and were overall less active compared to the CRFI gilts. This reduced activity could be a contributing factor to variation of residual feed intake (RFI) in pigs. This finding is consistent with what has been found in mice and chickens. To better quantify this, general behavioral activity of the individual pig would need to be examined relative to the specific level of observed RFI.

On the day of placement, there were differences for lesion scores, with the LRFI gilts scoring lower for all regions relative to the CRFI gilts. This finding provides little evidence, given current published research, as to if one of these lines is more likely to be the aggressor or bullied. No differences for lesion scores were observed over the length of the trial. Observed lesion scores were highest on the day of placement, as would be expected given the gilts were establishing a hierarchy. Over the trial, lesion scores increased, which was surprising given the stable living conditions. In general, this research points out that little is known about aggression interactions during the grow-finish phase of the pig. Regardless of
genetics, the relationship between displayed aggression, the aggressor, the recipient of the aggression and level of lesion scores need to be examined. Studies examining the specific aggression interactions between pigs, most likely through video, are needed to identify possible differences in levels of and interactions of aggression between lines. Additionally, work examining what would explain the increased lesion scores that were observed during the length of this trial would be helpful. On the day of placement, no differences were observed between lines regarding general behavioral activity, yet differences were observed between these lines regarding lesion scores. The opposite was true during the length of the trial. Therefore, the relationship between general behavioral activity and lesion scores during the grow-finish period are not strong. This assumption also needs to be further investigated.

When in the weigh scale, the LRFI line exhibited lower scale activity scores than the control line during an initial temperament score in a weigh scale. While both genetic lines’ temperament scores decreased over the trial, the CRFI gilts had a greater percentage decrease and scored lower than the LRFI gilts by the end. Exit score for the entire population of gilts over the grow-finish period increased. Work addressing the general coping mechanisms of adaptability between the genetic lines, and how this affects the overall well-being of the gilt is warranted. This may help to both parcel out and tie together how selection for RFI influences the general activity of the gilt, the relationship with lesion scores and temperament. Future studies should consider housing the two lines separately so that each line’s behaviors are not directly affected the other. This may help to establish larger
differences between the lines. Finally, work should be carried out similar to what has been completed in cattle to determine the relationship between temperament and production and final meat quality attributes. While additional research is needed to determine the specifics of how temperament may affect RFI, selection for RFI has been shown to not to have a detrimental effect.