1-2011

# Effects of selection for decreased residual feed intake on composition and quality of fresh pork

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# Effects of selection for decreased residual feed intake on composition and quality of fresh pork

**Abstract**

The objectives of this study were to determine the extent to which selection for decreased residual feed intake (RFI) affects pork composition and quality. Pigs from the fifth generation of selection for decreased RFI (select) and a randomly selected line (control) were utilized. Two experiments were conducted. In Exp. 1, barrows (22.6 ± 3.9 kg) from select and control lines were paired based on age and BW. The test was conducted in 8 replicates of pairs for the test period of 6 wk. Calpastatin activity and myosin isoforms profile were determined on samples from the LM. Control barrows were heavier (59.1 vs. 55.0 kg; $P < 0.01$) at the end of the test period. Calpastatin activity was greater ($P < 0.01$) in LM of select barrows than control barrows. In Exp. 2, composition and quality of gilts (114 kg) from control and select lines were determined. The model included fixed effects of line, slaughter date, melanocortin-4 receptor (MC4R) genotype, barn group, line × slaughter date, genotype × line interactions, a covariate of off-test BW, and sire, pen, and litter fitted as random effects. The select line (n = 80) had 0.043 kg less ($P < 0.05$) RFI per day than the control line (n = 89). Loin quality and composition were determined at 2 d postmortem. Desmin degradation was measured at 2 and 7 d postmortem. Purge, cook loss, sensory traits, and star probe texture were measured at 7 to 10 d postmortem on cooked chops. Residual correlations between RFI and composition and quality traits were calculated. Compared with the control line, carcasses from the select line tended to have less ($P = 0.09$) backfat, greater ($P < 0.05$) loin depth, and greater ($P < 0.05$) fat free lean. Loin chops from the select line had less ($P< 0.01$) intramuscular lipid content than loin chops from control line. Significant residual correlations between RFI and both tenderness (r = 0.24, $P < 0.01$) and star probe (r = −0.26, $P < 0.01$) were identified. Selection for decreased RFI has the potential to improve carcass composition with few effects on pH and water-holding capacity. However, decreased RFI could negatively affect tenderness and texture because of decreased lipid content and decreased postmortem protein degradation.

**Keywords**

pork composition, pork quality, residual feed intake, tenderness

**Disciplines**

Agriculture | Animal Sciences | Meat Science

**Comments**

This article is from *Journal of Animal Science* 89 (2011): 192–200, doi:10.2527/jas.2010-2861.

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JOURNAL OF ANIMAL SCIENCE
The Premier Journal and Leading Source of New Knowledge and Perspective in Animal Science

**The effect of selection for residual feed intake on general behavioral activity and the occurrence of lesions in Yorkshire gilts**

L. J. Sadler, A. K. Johnson, S. M. Lonergan, D. Nettleton and J. C. M. Dekkers

*J ANIM SCI* 2011, 89:258-266.
doi: 10.2527/jas.2009-2595 originally published online September 10, 2010

# The effect of selection for residual feed intake on general behavioral activity and the occurrence of lesions in Yorkshire gilts[1]

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**ABSTRACT:** The objectives of this study were to determine the effect of selection for improved residual feed intake on behavior, activity, and lesion scores in gilts in their home pen. A total of 192 gilts were used, 96 from a line that had been selected for decreased residual feed intake over 5 generations (LRFI) and 96 from a randomly bred control line. Gilts were housed in 12 pens (16 gilts/pen; 0.82 $m^2$/gilt) containing 8 gilts from each line in a conventional grow-finish unit. Twelve hours of video footage were 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 4 postures (standing, lying, sitting, and locomotion) and 1 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 body of a gilt was divided into 4 regions, with each region receiving a score of 0 (0 lesions) to 3 (5+ lesions). All statistical analyses used Proc Mixed of SAS. Data were analyzed separately for the day of placement and the subsequent 3 rounds. General activity was summarized on a percentage basis by each posture and behavior and subjected to an arcsine square root transformation to 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 decreased ($P < 0.045$) lesion scores on the day after 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 postural, behavior, or general activity differences between genetic lines, but LRFI gilts had decreased 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, gilt, lesion score, posture, residual feed intake



J. Anim. Sci. 2011. 89:258–266
doi:10.2527/jas.2009-2595

## INTRODUCTION

Fast-growing lean pigs require less feed to reach market weight (See, 2003). However, approximately 34% of differences in feed intake between pigs are not related to growth or backfat (Cai et al., 2008). Although past selection for lean growth has substantially improved feed efficiency in pigs, further improvements 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 decreased RFI animals displaying less 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

[1]This work was supported by National Pork Board Project Number 07-161 and Hatch Funds from the Department of Animal Science, Iowa State University (Ames). The authors thank Allison Meiszberg, Jill Garvey, Jennifer Young, and Weiguo Cai (Department of Animal Science, Iowa State University, Ames), John Newton and the staff at the Lauren Christian Swine Research Center (Iowa State University Bilsland Memorial Farm, near Madrid, IA), as well as Man-Yu (Department of Statistics, Iowa State University) for technical assistance.

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Received October 20, 2009.
Accepted September 7, 2010.

in pigs through the use of lesion scores (Turner et al., 2006). The extent to which selection for decreased RFI is associated with postural time budgets, 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 decreased RFI, alongside a randomly bred control line. After 4 generations of selection, the decreased 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 decreased RFI has resulted in correlated responses in behavior, activity, and lesion scores.

## MATERIALS AND METHODS

The protocol for this experiment was approved by the Iowa State University Institutional Animal Care and Use Committee.

### *Experimental Design*

The experiment was conducted from April 15 to August 14, 2008. A total of 192 gilts were used. One-half of the gilts were from a line that had been selectively bred for decreased RFI over 5 generations (**LRFI**) and the other one-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 4 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 (Osborne Industries Inc., Osborne, KS) 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 BW. All gilts originated from 69 litters. Group 1 began the study 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 study and data collection period. Group 1 gilts started the study at 104 ± 3 d of age and 41.73 ± 5.60 kg of BW. Group 2 was placed on the study 14 d later (April 29, 2008) and started the study at 92 ± 8 d of age and 37.6 ± 5.8 kg of BW. Group 2 gilts were allocated to pens 7 through 12 using the same methodology as described for group 1. At the end of the study, 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 study (LRFI, n = 93; and CRFI, n = 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 study.

### *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, IA. Gilts were housed in 1 room that contained 12 pens, 16 gilts/pen, providing 0.82 $m^2$/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 in length and 2.3 m in 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 1 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 lx, with the majority of the room, as established by taking readings at 1-m intervals throughout the room, being less than 5 lx. For each pen, a 2 nipple-type waterers (Edstrom, Waterford, WI) provided ad libitum access to water, and a Feed Intake Recording Equipment feeder, equipped with the ACCU-ARM Weigh Race (FIRE, Osborne Industries Inc., Osborne, KS, http://www.osbornelivestockequipment.com/product_pages/fire/literature/fire_en.pdf) provided ad libitum access to a standard finishing diet. The FIRE feeder contained a long race leading to the feed trough. This ensured that only 1 gilt could consume feed at a time and offered protection to the face and sides of the gilt while she was in the feeder. The FIRE feeder was 1.2 m long and 0.7 m wide. Two diets, which were formulated to meet or exceed the requirements for growing pigs (NRC, 1998), were provided during the time the gilts were in the study. Diets were switched when the majority of gilts were approximately 79 kg. On an as-fed basis, the ME was 3,312 kcal per kg and 3,337 kcal per kg for diets 1 and 2, respectively. Available lysine for these diets, as a percentage of weight of the feed, was 0.957 and 0.820. 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 minimum 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 study. Environmental variables were averaged to determine maximum, minimum, and average values for the whole study 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 study, 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., 2009). This resulted in 576 h of video (2 groups × 6 pens per group × 4 recordings × 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 1 side of the room to the other every 4 wk so that all gilts could be recorded. Gilts were moved 3 d before 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, Kenansville, NC) on their backs 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 2 experienced observers using the Observer software (The Observer, version 5.0.31 Noldus Information Technology, Wageningen, the Netherlands). Training was conducted between the 2 observers before scoring to ensure reliability. Each observer was assigned 6 pens to score throughout the study, with each scoring all gilts in the assigned pen for the duration of the study. At the end of all data scoring, 1 pen was scored by both observers. The observers had more than 98% agreement. Postures and behaviors that 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 4 postures (locomotion, standing, sitting, and lying down), 1 behavior (at drinker), and the category of unknown. Posture 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 one-half of her body length in the 5 s before the scan. Standing was defined as maintaining an upright and stationary body position by supporting the BW 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 BW. Lying down included both the sternal and lateral maintenance of a recumbent position. At drinker was defined as when the mouth of the gilt was in contact with the water nipple, regardless of posture. A default category of unknown, defined as the gilt could not be seen clearly enough for identification or her behavior or posture could not be seen clearly enough to identify, was used when appropriate.

### 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 1 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 body of a gilt was divided into 4 regions. Regions and scoring were adapted from Schmolke et al. (2004) and Turner et al. (2006). 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 score of 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 statistical analyses used Proc Mixed (SAS Inst. Inc., Cary, NC). In all cases, the Kenward-Rogers method was used for computing the denominator degrees of freedom of the test. The data were analyzed separately for the day of placement and for subsequent

**Table 1.** Descriptive statistics for temperature and relative humidity by month in the production room during the length of the study, April 15 to July 14, 2008

| | Month[1] | | |
|---|---|---|---|
| Variable | 1 | 2 | 3 |
| Air temperature, °C | | | |
| Minimum | 12.40 | 12.98 | 16.35 |
| Maximum | 27.80 | 31.28 | 32.64 |
| Average | 20.20 | 22.85 | 24.80 |
| Relative humidity, % | | | |
| Minimum | 26.83 | 30.50 | 32.85 |
| Maximum | 100.00 | 97.41 | 99.83 |
| Average | 60.90 | 62.77 | 69.30 |

[1]A month began on the 15th of the calendar month running through the 14th of the following calendar month.

rounds of recording (1, 2, and 3). Because the category unknown was often 0 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 at the drinker. 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, BW around the time of recording (within 3 d) 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 × region; random effects of litter, group, and pen; and BW 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 a first-order autoregressive variance-covariance structure for residuals.

## RESULTS

### *Indoor Environmental Measurements*

During the first month that gilts were on the study (April 15, 2008 to May 14, 2008), the average temperature was around 20°C with an average RH of 61% (Table 1). Temperature increased slightly throughout the study, but RH experienced large increases, rising to an average of 79% during the last month. On the day of placement, temperature was around 20°C for both groups and remained fairly constant for each recording period until round 3, when the average temperature was around 29°C and an average RH over 78% (Table 2).

### *General Activity*

On the day of placement, no differences in behavior were observed between the 2 lines (Table 3). Gilts spent the majority of their time inactive (84.2%). When ac-

**Table 2.** Descriptive statistics for temperature and relative humidity by behavioral recording day in the production room[1]

| | Day of placement | | Round 1 | | Round 2 | | Round 3 | |
|---|---|---|---|---|---|---|---|---|
| Item | Group 1[2] | Group 2[3] | Group 1 | Group 2 | Group 1 | Group 2 | Group 1 | Group 2 |
| Air temperature, °C | | | | | | | | |
| Minimum | 18.71 | 16.61 | 19.89 | 18.20 | 18.10 | 19.27 | 23.97 | 23.52 |
| Maximum | 21.39 | 20.86 | 25.69 | 24.35 | 25.34 | 24.66 | 28.64 | 31.54 |
| Average | 20.64 | 19.67 | 23.17 | 20.78 | 22.46 | 21.56 | 28.64 | 28.72 |
| Relative humidity, % | | | | | | | | |
| Minimum | 30.62 | 42.79 | 27.76 | 60.23 | 38.81 | 82.52 | 65.18 | 69.48 |
| Maximum | 42.64 | 76.55 | 61.93 | 83.98 | 61.15 | 97.32 | 92.56 | 93.02 |
| Average | 35.67 | 55.73 | 37.67 | 74.01 | 47.28 | 91.51 | 78.26 | 78.61 |

[1]Day of placement temperatures were recorded ~1100 to 2300 h for group 1 and ~1000 to 2200 h for group 2. For all subsequent rounds, temperature values were recorded from 0800 to 2000 h.

[2]Group 1: April 15, 2008.

[3]Group 2: April 29, 2008.

**Table 3.** Time budget of 2 genetic lines of grow-finish gilts on the day of placement, in the home pen[1]

| | Genetic line[4] | | | |
|---|---|---|---|---|
| Variable[2,3] | LRFI | CRFI | SE | $P$-value[5] |
| Posture, % | | | | |
| Locomotion | 4.25 | 4.00 | 1.59 | 0.728 |
| Standing | 10.30 | 11.90 | 2.94 | 0.113 |
| Sitting | 2.25 | 1.98 | 0.37 | 0.503 |
| Lying | 82.70 | 81.60 | 5.02 | 0.342 |
| Active[6] | 15.09 | 16.38 | 5.09 | 0.285 |
| Inactive[7] | 84.88 | 83.54 | 5.03 | 0.270 |
| Behavior, % | | | | |
| At drinker | 0.46 | 0.50 | 0.13 | 0.778 |

[1]Values are least squares means for 96 gilts per genotype.

[2]Postures adapted from Hurnik et al. (1985).

[3]Postures and behavior were observed using a 10-min instantaneous scan sample technique.

[4]Genetic line: decreased residual feed intake (LRFI, n = 96) gilts, which had been selectively bred for decreased residual feed intake over 5 generations, and control residual feed intake (CRFI, n = 96) gilts from a randomly bred line.

[5]Established using transformed data.

[6]Active is the combination of the postures locomotion and standing and the behavior at drinker.

[7]Inactive is the combination of the postures sitting and lying.

tive, 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 4). Regardless of line, the gilts spent the majority of their time inactive (82%). The round × line interaction was not different ($P > 0.05$) for all behavior and posture categories except sitting ($P = 0.016$), showing the LRFI line sat less during round 1 and 3 ($P < 0.05$), but was not different from the CFRI line during round 2 ($P = 0.721$).

When examining the entire population of gilts over the 3 subsequent rounds, no differences for time sitting or time at the drinker were detected at the $P < 0.05$ level (Table 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 with rounds 1 and 3, respectively ($P < 0.001$, Table 5).

**Table 4.** Time budget of 2 genetic lines of grow-finish gilts over the subsequent rounds, in the home pen[1]

| | Genetic line[4] | | | |
|---|---|---|---|---|
| Variable[2,3] | Estimate for LRFI[6] | Estimate for CRFI | SE | $P$-value[5] |
| Posture, % | | | | |
| Locomotion | 2.26 | 2.37 | 0.17 | 0.577 |
| Standing | 13.72 | 15.21 | 0.88 | 0.027 |
| Sitting | 2.50 | 2.12 | 0.28 | 0.051 |
| Lying | 80.23 | 79.16 | 0.92 | 0.179 |
| Active[7] | 16.88 | 18.50 | 0.82 | 0.028 |
| Inactive[8] | 82.70 | 81.33 | 0.87 | 0.063 |
| Behavior, % | | | | |
| At drinker | 0.88 | 0.93 | 0.09 | 0.523 |

[1]Values are least squares means for 96 gilts per genotype.

[2]Postures adapted from Hurnik et al. (1985).

[3]Postures and behavior were observed using a 10-min instantaneous scan sample technique.

[4]Genetic line: decreased residual feed intake (n = 96) gilts, which had been selectively bred for decreased residual feed intake over 5 generations, and control residual feed intake (n = 96) gilts from a randomly bred line.

[5]Established using transformed data.

[6]Estimates are averages of the 3 rounds. LRFI = decreased residual feed intake gilts; CRFI = control residual feed intake gilts.

[7]Active is the combination of the postures locomotion and standing and the behavior at drinker.

[8]Inactive is the combination of the postures sitting and lying.

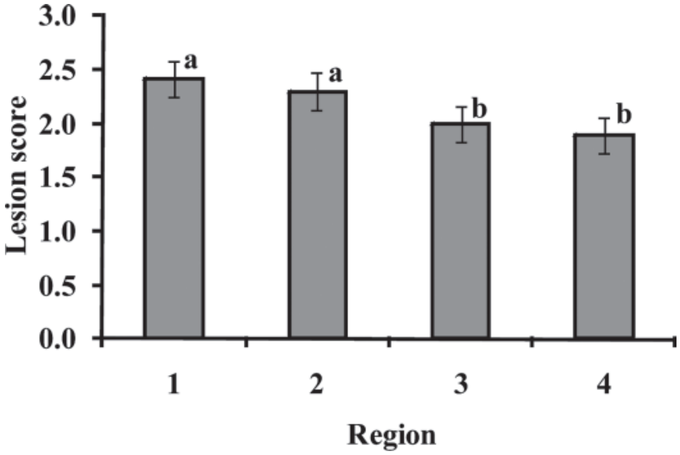


**Figure 1.** Lesion score, by region, for all grow-finish gilts on the day of placement. Values (columns) are least squares means, for each region scored on the gilts, averaged across genetic lines: decreased residual feed intake and control residual feed intake (n = 192). Differences between lines and a line × region interaction were observed ($P < 0.05$); see text for details. Letters (a,b) indicate differences between columns (regions) that differ at $P$-value <0.05. 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.

### *Lesion Scoring*

On the day after placement, across all regions, the LRFI gilts had decreased (2.03 ± 0.12) lesion scores compared with the CRFI (2.27 ± 0.12) gilts ($P = 0.045$). By examining the line × region interaction ($P < 0.05$), the LRFI gilts had decreased scores for all regions compared with the CRFI gilts (not in table), although this was not different ($P = 0.85$) for region 4. Across lines, regions 1 and 2 had greater ($P < 0.001$) lesion scores than regions 3 and 4, and there was no difference between region 1 and region 2 regardless of genetic line (Figure 1).

There was no 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 2 lines, lesion scores increased ($P < 0.001$) over rounds 1, 2, and 3 (Figure 2). This increase with round was observed for each region (Figure 3), although region 3 had decreased scores compared with regions 1, 2, and 4. None of the interactions were significant ($P > 0.05$), except the round × region interaction ($P = 0.016$). During all rounds, regions 1 and 2 were not 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 different ($P > 0.10$). Region 3 was different ($P < 0.05$) from all other regions for every round.

## DISCUSSION

Analysis of the first 4 generations of the selection experiment conducted at Iowa State University for RFI (Cai et al., 2008) indicated that RFI is moderately heritable ($h^2 = 0.29$) and that selection for decreased RFI had successfully reduced feed intake by 0.18 kg/d, which represents a 10% reduction. Selection for decreased 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 SD and an associated increase in feed efficiency from ~0.38 kg of growth per kilogram feed required to ~0.40 kg.

### *Behavioral Repertoire Differences Between Increased RFI and Decreased RFI Animals*

Limited scientific information is available pertaining to alterations in the behavioral repertoire between increased or decreased 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) suggested that differences may

**Table 5.** Time budget of grow-finish gilts over the subsequent rounds, by round, in the home pen[1]

| | Round 1 | | Round 2 | | Round 3 | | |
|---|---|---|---|---|---|---|---|
| Variable[2,3] | Estimate[5] | SE | Estimate[5] | SE | Estimate[5] | SE | $P$-value[4] |
| Posture, % | | | | | | | |
| Locomotion | 3.07[a] | 0.17 | 2.37[a] | 0.17 | 0.60[b] | 0.11 | <0.001 |
| Standing | 14.12[ab] | 1.00 | 15.96[b] | 0.90 | 13.32[a] | 0.97 | <0.001 |
| Sitting | 1.95 | 0.35 | 2.51 | 0.29 | 2.46 | 0.37 | 0.143 |
| Lying | 80.24[a] | 1.10 | 77.36[b] | 0.95 | 81.51[a] | 1.06 | <0.001 |
| Active[6] | 18.09[a] | 0.98 | 20.13[b] | 0.86 | 14.86[c] | 0.91 | <0.001 |
| Inactive[7] | 81.89[a] | 1.04 | 79.85[b] | 0.89 | 84.31[c] | 0.98 | <0.001 |
| Behavior, % | | | | | | | |
| At drinker | 0.87 | 0.15 | 0.88 | 0.10 | 0.96 | 0.16 | 0.962 |

[a–c]Superscripts indicate differences within a row at $P$-value <0.001; values were established using transformed data.
[1]Values are least squares means for genetic lines: decreased residual feed intake and control residual feed intake (n = 192).
[2]Postures adapted from Hurnik et al. (1985).
[3]Postures and behavior were observed using a 10-min instantaneous scan sample technique.
[4]Established using transformed data.
[5]Estimates are for the average of the 2 genetic lines, within each round.
[6]Active is the combination of the postures locomotion and standing and the behavior at drinker.
[7]Inactive is the combination of the postures sitting and lying.

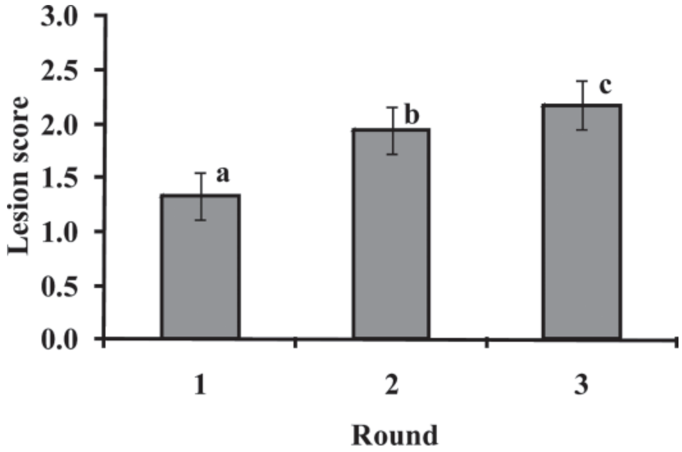


**Figure 2.** Lesion score, by round, for all grow-finish gilts during the subsequent rounds. Values (columns) are least squares means during each round, averaged across genetic lines: decreased residual feed intake and control residual feed intake (n = 192). There were no effects of genetic line on lesion scores ($P = 0.66$). A round × region interaction was observed ($P < 0.05$); see text for details. Letters (a–c) indicate differences between columns (rounds) that differ at $P$-value <0.05. Round 1 = 30 d after the day of placement. Round 2 = 28 d after round 1. Round 3 = 28 d after round 2.

exist between animals with different RFI. Robinson and Oddy (2004) noted a tendency for cattle that ate fewer meals per day to have decreased RFI; in addition, these mixed sex cattle had less subcutaneous fat. Furthermore, Robinson and Oddy (2004) 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 reduced efficiency (greater RFI) spent more time food-pecking, walking, and pacing compared with hens that were divergently bred for increased efficiency (reduced RFI). Rauw et al. (2000) subjected an increased RFI line vs. a control line of nonreproductive adult female mice obtained from a Norwegian mouse selection experiment to a series of tests to determine differences in their coping strategies. The increased RFI line came from selection for large litters, which resulted in increased RFI. The authors found that mice from the increased 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 et 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 (2004) acknowledged that RFI had a greater 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, we found that gilts from the LRFI line spent approximately 2% less time engaged in active behaviors, or an 8.8% reduction of activity, in their home pen environment. It is interesting to note this is close to the 10% reduction observed in feed intake of this line. 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 amount of activity decreases 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, 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 reduced activity score overall.

Previous work by Rauw et al. (2000) addressed aggressive or coping styles of mice bred to be more efficient and reported that during a social confrontation test, mice from the increased RFI line investigated the

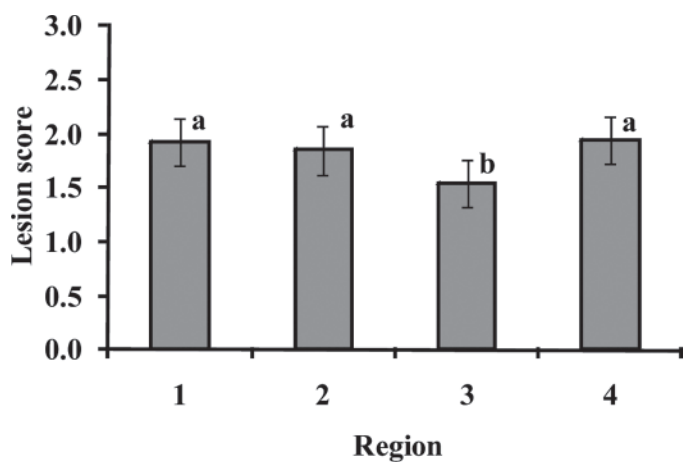


**Figure 3.** Lesion score for all grow-finish gilts during the subsequent rounds by region. Values (columns) are least squares means, for each region scored on the gilts, averaged across genetic lines, reduced residual feed intake and control residual feed intake (n = 192). There were no effects of genetic line on lesion scores ($P = 0.66$). A round × region interaction was observed ($P = 0.016$); see text for details. Letters (a,b) indicate differences between columns (regions) that differ at $P$-value <0.05. 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.

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) found that group-housed grow-finish pigs spent more time standing than their individually housed counterparts. Gonyou et al. (1992) 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 2 lines used in this study have not been quantified.

The amount of time at the drinker did not change over the study. Several factors could contribute to this. Body weight at the time of recording was included in the model as a covariate; however, removing this did not change the results for significance over the subsequent rounds. Because 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 study. Drinking was always less than 1%, and the smallest 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. Reduced efficiency (increased RFI) White Leghorn laying hens showed more attempts of escape and aggression-related behaviors compared with hens that were divergently bred for increased efficiency (reduced 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 lesions is a methodology that has been proposed as a means to determine pig welfare and in turn to predict the amount of aggression that a pig has delivered or sustained. Olesen et al. (1996) and Ayo et 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. Turner et al. (2006) investigated determinates of the accumulation of lesions and found that individual pig BW was the single greatest determinant of lesion scores. In this study, gilt BW was a significant covariate and was thus included in the model. Our model predicted a 1-unit increase in lesion score for every 35.2-kg increase in gilt BW 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 corresponded 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 lesions on the back third of the body (defined as region 4 in our work). In our study, pigs from the LRFI line had decreased lesion scores, which may indicate that these pigs are less aggressive, or more often lost the aggressive encounter. It could be hypothesized that this decreased aggression contributes to the decreased 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 less in all regions. The use of the FIRE feeder may have affected the accumulation of lesion scores in the pigs. It could be hypothesized with only 1 feeding space per 16 gilts, competition for the feeding resource would have been greater than with a conventional feeder, resulting in greater lesion scores. Conversely, the FIRE feeder offered the gilt greater protection than a traditional feeder, possibly allowing them to consume more feed with less competition. If competition was intense during the subsequent rounds, greater lesion scores would have been expected in region 4 and reduced scores in the other regions. What was found were lesion scores similar for regions 1, 2, and 4. Perhaps this indicates that aggression was greater both outside and in the feeder. Additionally, it could by hypothesized the CRFI line had greater lesion scores because they were the ones that often lost the aggression encounter. 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. It may also be of benefit to examine other aspects of the aggression encounters such as where in the pen they occur, what time of day, the number of aggression bouts, and their length. Examining this would help to parcel out how the FIRE feeder may have affected the LRFI line compared with the CRFI line.

Lesion scores were greater the day after placement, which would be expected during the time of hierarchy establishment. The score of the entire population was least for round 1, which was 28 d after placement, and increased for every subsequent round. This could in theory be caused by several factors, such as increased ability to be injured (e.g., if the skin damaged easier, 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 greatest score (apart from the day of placement), given that this round also had the least 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 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 LRFI had reduced 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.

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