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Effects of genetic selection for residual feed intake on behavioral reactivity of castrated male pigs to novel stimuli tests

Jessica D. Colpoys[a], Caitlyn E. Abell[b], Jennifer M. Young[a,1], Aileen F. Keating[a], Nicholas K. Gabler[a], Suzanne T. Millman[c], Janice M. Siegford[d], Anna K. Johnson[a,*]

[a] Department of Animal Science, Iowa State University, 2356-F Kildee Hall, Ames, IA 50011, USA
[b] DNA Genetics, 2415 13th St., Columbus, NE 68601, USA
[c] Department of Veterinary Diagnostics and Production Animal Medicine, Lloyd Veterinary Medical Center, College of Veterinary Medicine, Iowa State University, Room 2440, 1600 South 16th St., Ames, IA 50011, USA
[d] Department of Animal Science, Michigan State University, 474 S. Shaw Lane, Room 1290, East Lansing, MI 48824, USA

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Increasing feed efficiency in swine is important for increasing sustainable food production and profitability for producers; therefore, this is often selected for at breeding. Residual feed intake (RFI) can be used for the genetic selection of pigs for feed efficiency. In our selection project, low-RFI pigs consume less feed for equal weight gain compared to their less efficient, high-RFI counterparts. However, little is known about how feed efficiency influences the pig's behavioral reactivity toward fear-eliciting stimuli. In this study, behavioral reactivity of pigs divergently selected for RFI was evaluated using human approach-(HAT) and novel object tests (NOT). Forty low-RFI (more feed efficient) and 40 high-RFI (less feed efficient) castrated male pigs (barrows; 46.5 ± 8.6 kg) from 8th generation Yorkshire RFI selection lines were randomly selected and evaluated once using HAT and once using NOT over a four week period utilizing a crossover experimental design. Each pig was individually tested within a 4.9×2.4 m test arena for 10 min; behavior was evaluated using live and video observations. The test arena floor was divided into four zones; zone 1 being oral, nasal, and/or facial contact with the human (HAT) or orange traffic cone (NOT) and zone 4 being furthest from the human or cone and included the point where the pig entered the arena. During both HAT and NOT, low-RFI pigs crossed fewer zones ($P < 0.0001$), had fewer head movements ($P \leq 0.02$), defecated less frequently ($P \leq 0.03$), displayed a shorter duration of freezing ($P = 0.05$), and froze less frequently (HAT: low-RFI = 4.9 ± 0.65 vs. high-RFI = 7.5 ± 0.96; NOT: low-RFI = 4.7 ± 0.66 vs. high-RFI = 7.2 ± 0.96; $P < 0.0001$) compared to high-RFI pigs. During HAT, low-RFI pigs also attempted to escape less frequently (low-RFI = 0.4 ± 0.14 vs. high-RFI = 1.1 ± 0.30; $P = 0.001$) compared to high-RFI pigs. In contrast, compared to the high-RFI pigs, low-RFI pigs took 48 s longer during HAT and 52 s longer during NOT to approach zone 1 ($P \leq 0.04$). These results indicate that low-RFI pigs had

Abbreviations: RFI, residual feed intake; HAT, human approach test; NOT, novel object test; HPA, hypothalamic-pituitary-adrenocortical.

* Corresponding author. Tel.: +001 515 294 2098; fax: +001 515 294 4471.
E-mail addresses: johnsona@iastate.edu, usanduk73@gmail.com (A.K. Johnson).
[1] Present address: Department of Animal Sciences, North Dakota State University, Hultz Hall, Room 123, Fargo, ND 58108, USA.

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decreased behavioral reactivity during HAT and NOT compared to high-RFI pigs. This may suggest that reducing a pig's behavioral reactivity is an important component of improving feed efficiency; however, it may have implications for animal handling and facility design.
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1. Introduction

Increasing feed efficiency is an important objective for livestock production. Better feed efficiency can improve producer profitability, increase production for feeding a growing world population and improve environmental sustainability (Nkrumah et al., 2006; Wall et al., 2010). In place of traditional gross efficiency (gain:feed) and feed conversion (feed:gain) ratios, many investigators have begun using residual feed intake (RFI) as an alternative method to measure feed efficiency (Koch et al., 1963; Cai et al., 2008). The Iowa State University Yorkshire RFI selection project uses a RFI model that defined the difference between the actual feed intake of an animal and its expected feed intake based on a given amount of growth and back fat. Therefore, pigs that consume less feed than expected for maintenance and growth have a lower RFI, are more feed efficient, and they are therefore economically better for lean production relative to higher RFI pigs (Young et al., 2011).

Numerous studies have been conducted to examine the physiology of feed efficiency using divergent RFI models. Specifically in pigs, RFI research has focused on feed intake patterns (Young et al., 2011), physical activity (Sadler et al., 2011), body composition (Boddicker et al., 2011a,b), nutrient digestibility (Barea et al., 2010; Harris et al., 2012), immune system activation (Rakhshandeh et al., 2012), skeletal muscle oxidative stress (Grubbs et al., 2013) and protein turnover (Cruzen et al., 2013). Furthermore, the hypothalamic-pituitary-adrenocortical (HPA) axis has been shown to be an important contributor to feed efficiency in pigs (Hennessy and Jackson, 1987), sheep (Knott et al., 2008, 2010), and poultry (Katle et al., 1988). These studies have revealed a relationship between higher feed efficiency and a lower glucocorticoid response. However, there is no consensus and it remains unclear whether improved feed efficiency alters behavior in livestock (Braastad and Katle, 1989; Luiting et al., 1994; Amdi et al., 2010).

Novelty has been utilized in studies of pig stress responses to a human approach—(HAT; Hemsworth et al., 1981; Gonyou et al., 1986; Janczak et al., 2003) and novel object test (NOT; Hemsworth et al., 1996; Dalmau et al., 2009; de Sevilla et al., 2009). An animal's response to HAT and NOT can help further our understanding of the animal's responsiveness to stress, which can in turn impact the animal's welfare during routine handling and husbandry. It was recently suggested that breeding for improved feed efficiency, and particularly for reduced RFI, may decrease the animal's ability to adapt to stress (Rydhmer and Canario, 2014). Therefore, the objective of this study was to examine the association between long-term divergent selection for RFI and behavioral reactivity to fear-eliciting stimuli. The hypothesis that low-RFI pigs would be less behaviorally reactive compared to high-RFI pigs was specifically tested by determining if divergent line selection for RFI influenced pigs' behavioral reactivity to HAT and NOT. These data will help develop breeding, handling, and management strategies to optimize feed efficiency in swine.

2. Materials and methods

All experimental procedures were approved by the Iowa State University Animal Care and Use Committee. This experiment was conducted over four consecutive weeks from October through November, 2011.

2.1. Animals and housing

A total of 80 healthy Yorkshire castrated male pigs (barrows; 46.5 ± 8.6 kg test day body weight) divergently selected for RFI were used. Half (20 low-RFI and 20 high-RFI) of the pigs were fed a low-fiber, high-energy diet (9.4% neutral detergent fiber, 13.86 MJ of metabolizable energy/kg of feed) and half were fed a high-fiber, low-energy diet (25.9% neutral detergent fiber, 11.97 MJ of metabolizable energy/kg of feed). Both diets met or exceeded NRC (1998) requirements and further information regarding ingredient and nutrient analysis is explained by Colpoys et al. (2014). Two genetic line treatments were compared: low-RFI ($n = 40$) and high-RFI ($n = 40$). Divergent line selection criteria were based on estimate breeding values for RFI as explained by Cai et al. (2008). The low-RFI genetic line had been selected over eight generations whereas the high-RFI genetic line had been randomly selected over five generations, and then selectively bred for high-RFI over the next three generations.

This work was conducted at the Lauren Christian Swine Research Center at the Iowa State University Bilsland Memorial Farm, near Madrid, Iowa, USA. All pigs were housed in a conventional confinement unit within one room containing 12 mixed-sex and mixed-line pens of 15 to 16 pigs/pen; five to eight pigs from each pen were tested. The pigs were moved to this facility 10 days prior to the start of the experiment. Each pen measured 5.6 m long × 2.3 m wide and had a slatted concrete floor. The barn was naturally ventilated with side curtains. Each pen contained an electronic one-space feeder (FIRE®, Osborne Industries, Inc., Osborne, KS, USA) that recorded the feed intake of each pig, positioned at the front of the pen to provide pigs with ad libitum feed. Water was provided ad libitum through two nipple-type waterers (Edstrom, Waterford, WI, USA) per pen. One electronic recording device (HOBO Pro v2, temp/RH, U23-001, Onset Computer Corporation, Bourne, MA, USA) located in the center of the room, 2.2 m from the ground, recorded ambient temperature (°C) and relative humidity (%) every 5 min for the duration of the trial. The mean (±S.D.) ambient

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