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The genetic and biological basis for differences in feed efficiency between selection lines for residual feed intake

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Introduction and background

With the rise in feed costs, increasing nutritional efficiency of production is, more than ever, one of the main drivers of profitability of pork production. Over the past decades, substantial effort has been placed on increasing feed efficiency. On the genetics side, this has indirectly been accomplished by selection for growth rate and leanness, which both decrease the amount of feed required to reach market weight. It is well known, however, that a large proportion (~34%) of differences in feed intake between pigs are not related to growth and backfat but result from differences in energy required for other processes such as maintenance, activity, and digestive and metabolic efficiency. These differences between the amount of feed that a pig actually consumes and what it is expected to need to sustain its growth rate and backfat deposition is called residual feed intake (RFI) (Koch et al. 1963). Thus, RFI represents variation in feed intake that is not related to growth and backfat and pigs with lower RFI are more efficient because they require less feed to sustain the level of growth and backfat that they achieve.

ISU selection lines for residual feed intake

To enable research into the biological and genetic basis of feed efficiency during the growing phase, a selection experiment was started in 2001 in purebred Yorkshire pigs. Consisting of a line selected for lower RFI (i.e. increased efficiency), along with a randomly selected control, analysis of the first 4 (Cai et al., 2008) and 5 (Bunter et al., 2010) generations of the ISU RFI selection lines has shown that RFI is moderately heritable (h^2 = 0.25 to 0.31) and that selection for lower RFI has successfully reduced feed intake and increased feed efficiency. Starting generation 5, the control line has been selected for increased RFI (reduced efficiency), in order to further increase differences in feed efficiency between the lines. In generation 7, pigs from the low RFI line consumed 255 g/d less than the high line, representing a 13% reduction in feed intake. Selection for reduced RFI has, however, also resulted in some declines in growth rate (~14g/d) and backfat (~2.7 mm) but the amount of feed required for a given amount of growth and backfat has been reduced by 9%, resulting in a decrease in feed conversion from ~2.66 kg feed per kg growth to ~2.36.

Factors contributing to differences in RFI

Once we had shown that feed efficiency measured by RFI was heritable and responded to selection, and had established sizeable differenced in efficiency between the two lines, we were in an ideal position to utilize these unique lines to investigate the biological and genetic basis of feed efficiency. We did this in a recently completed interdisciplinary research project that was jointly funded by the National Pork Board and the Iowa Pork Producers Association. This research demonstrated that, compared to the control line, pigs from the efficient line: 1) had different feeding behavior, as they ate faster and less often (Young et al. 2011), 2) tended to be slightly less active but did not differ much in other behaviors that were studied (Sadler et al. 2011), 3) were more efficient under both ad libitum and restricted feeding (Boddicker et al. 2011), 4) required less feed to maintain a constant weight (Boddicker et al. 2011), 5) tended to have lower internal organ weights (Boddicker et al. 2011), 6) had a lower fat content of the carcass (Boddicker et al. 2011), 7) in general had better carcass composition and dressing percentage, with limited effects on selected measures of meat quality such as pH and water holding capacity (Smith et al. 2011), 8) had decreased carcass lipid content and postmortem protein degradation (Smith et al. 2011), 9) had physiological parameters that indicated less protein turnover and energy expenditure in muscle. Our overall conclusion from this work was that, although a substantial part of differences in feed efficiency as measured by RFI were related to differences in body composition, part of the differences were related to pen and feeding behavior and to lower maintenance requirements and energy expenditures. Selection for RFI did not have major negative effects on meat quality.

Impact of selection for RFI on sow performance

In recent research funded by the NPB, we have also investigated the impact of selection for feed efficiency

during the growing phase on feed efficiency during lactation and reproductive performance (Young et al. 2010). Contrary to what was expected, selection for reduced RFI (increased efficiency) during the growing phase had no detrimental effects on sow performance. In fact, and this was replicated in a similar selection that is ongoing at INRA in France (Gilbert et al. 2007), there was some evidence of improved sow performance in the low RFI lines in the form of slightly larger litters, birth weights, and pre-weaning growth, despite lower feed intake during lactation. Although sows were lighter at farrowing in the low RFI line in the INRA experiment, these differences were not significant in the ISU experiment. Sows from the low RFI lines did lose more body weight and backfat during lactation to sustain the increased level of litter performance. Residual feed intake during lactation, evaluated by adjusting feed intake for body weight, loss of body weight and backfat, and gain of the nursed litter, was lower in the low RFI line at INRA but not at ISU. Rebreeding performance was not evaluated.

Metabolic and genetic markers for RFI

Selection for feed efficiency requires recording of feed intake on individual pigs, which is expensive. An attractive alternative would be the use of metabolic or genetic markers that are associated with feed efficiency, in particular if pigs can be evaluated for these markers or marker traits at an early age.

IGF-I concentration in blood has been proposed as an early indicator of efficiency in cattle and pigs. In collaborative research with scientists in Australia, the ISU RFI lines were also found to differ in concentration of IGF-I in blood at an early age (Bunter et al. 2010), with the efficient line having lower IGF-I. This finding confirmed the utility of early IGF-I in blood as a tool to select for efficiency but these results must be validated in other populations and in other environments

The ISU RFI lines are currently also used to identify genetic markers for feed efficiency using candidate genes and a genome-wide association study based on genotyping pigs from the two lines with the high-density SNP chip, with over 60,000 genetic markers across the genome. Initial results from this work has identified several genetic markers that might be useful to develop genetic tests for feed efficiency (Fan et al. 2010, Gorbach et al. 2010).

Performance of low RFI Pigs under stress

All selection decisions for the ISU RFI lines and the research described above have been conducted while pigs were fed standard corn-soybean diets in farm with a relatively high health status. To investigate how pigs selected for increased efficiency perform when subjected to different stressors, several experiments will conducted with the ISU RFI lines under a recently funded USDA-AFRI grant. This includes dietary stressors (high-fiber diets with dried distillers grain with solubles), immune and disease stressors (LPS and PRRSv challenge), and several behavioral stressors. Recently completed work with PRRS challenge under the nursery pig model at Kansas State (Rowland et al.) found no differences in growth under PRRS challenge between the two lines. In fact, the efficient line tended to have slightly greater growth under challenge. In related metabolic studies funded by USDA (Gabler et al.), pigs from the efficient line were found to have lower levels of serum endotoxin levels because of more robust intestinal detoxification and epithelial defense mechanisms.

Conclusions

Residual feed intake evaluated differences in feed efficiency between pigs independent of growth and backfat. RFI is a trait with moderate heritability in growing pigs. Selection on RFI has been effective in creating lines of pigs that differ in feed intake and in RFI. Changes in body composition explain a substantial portion of line differences in RFI, even after adjusting to constant backfat. Selection for lower RFI resulted in faster eating pigs and pigs that appear to have reduced basal maintenance requirements, reduced tissue turnover rates, and a shift in mechanisms for use and storage of energy towards short-term storage. Selection for reduced RFI had no detrimental effects on sow performance. Low RFI sows in fact had slightly higher litter size and pre-weaning litter growth, despite lower feed intake during lactation, but this was at the expense of low RFI sows mobilizing more body reserves. Serum IGF-I at an early age has the potential to be a useful early indicator for feed efficiency to be used in selection, along with genetic markers associated with feed efficiency and RFI.

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