Research in Gilt Development to Improve Lifetime Productivity of Sows

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USDA, ARS, USMARC, Reproduction Research Unit,
The need to improve lifetime productivity

- A gilt must remain in the herd for 3 parities to recoup the initial investment
- Nearly 50% of breeding age females are culled each year
  - Avg. Parity 3.5
- Top Culling Reasons
  - Reproductive Failure
  - Locomotion/lameness
  - Litter performance
  - Age
What is a successfully developed gilt?

- Adequate **growth** and composition (1.3-1.5 lb/d LTGR)
- Reach **puberty** early – age at 1\(^{st}\) estrus (70%; 3 wks)
- P0 fertility – **conceive** first breeding (210 d of age)
- P1 gestation - **litter size** (> 12 NBA)
- P1 lactation performance (# weaned + litter weight)
- Postweaning **fertility** (estrus & conception)
- **Stay** in herd for multiple parities (> 50 pigs/bred gilt)

**How do you preselect a gilt with this future phenotype?**

**Can it be programmed?**
During critical periods of development, external factors (e.g., nutrient level, stress, environment) alter animal phenotype through changes in gene expression.

These modifications in gene expression can permanently change an animal’s long-term production potential.

Figure adapted from Bartol et al., 2008, Reprod Dom Animal 43(Suppl. 2):273-279
When can development be programmed

Developmental programming

Days from conception

Development

0 50 100 150 200 250 300 350 400

Birth

Wean

Puberty

Breeding

Prenatal programming

Postnatal programming
# Key periods of development of the reproductive system occur during the first 100 d of a gilt's life

<table>
<thead>
<tr>
<th>Organ</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pituitary</strong></td>
<td></td>
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<tr>
<td>Responds to ovarian steroids</td>
<td>6-10 d</td>
</tr>
<tr>
<td><strong>Uterus</strong></td>
<td></td>
</tr>
<tr>
<td>Development of glands</td>
<td>7-30 d</td>
</tr>
<tr>
<td>Growth – independent of ovaries</td>
<td>0-100 d</td>
</tr>
<tr>
<td>Growth – dependent on ovaries</td>
<td>&gt;100</td>
</tr>
<tr>
<td><strong>Ovary</strong></td>
<td></td>
</tr>
<tr>
<td>Development of primary follicles</td>
<td>0-30 d</td>
</tr>
<tr>
<td>Develops visible follicles</td>
<td>60-100 d</td>
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<tr>
<td>Responds to pituitary hormones</td>
<td>&gt;100</td>
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<tr>
<td><strong>Brain</strong></td>
<td></td>
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<tr>
<td>Responds to ovarian steroids</td>
<td>60 d</td>
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<tr>
<td>Turns on reproduction</td>
<td>Puberty</td>
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</tbody>
</table>
Gilts nursed in small litters:

- Increase pre- and post-weaning growth rate (Klindt et al., 2003; Lents et al., 2014).
- Reach puberty earlier (Flowers, 2011).
- Larger litter size (Rutledge, 1980; Flowers, 2011).

Boars:

- 20% Larger testes and produced 15% more sperm (Flowers, unpublished).

Most studies very small and use older genotypes.
Programming gilt development

Litter Size (within 24-48 hr)
- Spring born
  - Small: 8 pigs/litter
  - Large: 14 pigs/litter
- Fall born
  - Small: 8 pigs/litter
  - Large: 14 pigs/litter

- Collect important tissues at key developmental time points
  - Weaning, 60, 100, 140 days of age
  - Ovary and uterus
Analysis of gilts collected at 140 d of age

- Ovary weight, g
- Ovarian follicles, No.
- Uterine horn length, cm

Determine developmental course of these traits in gilts collected at weaning, 60, and 100 d of age.
Programming gilt development

- **Effect of litter size on ovarian histology & morphology**
  - Gilts from smaller litters had larger ovaries with more follicles
  - Gilts from small litters have greater ovulation rate (Martin and Chrenshaw, 1989)

- **Effect of litter size on uterine length**
  - Gilts raised in small litters had longer uterine horns.
  - Genetic selection for increased uterine capacity resulted in gilts with longer uterine horns (Lents et al., 2014).

- **Litter size programs reproductive tract development**
  - Increased number of follicles – increased ovulation rate
  - Longer uterine horns – greater uterine capacity
Results emphasize:

1) The need to understand how uterine capacity is controlled.
   - This can be accomplished by understanding the genes involved in neonatal programming of component traits (e.g., uterine length) of uterine capacity.

2) The need to estimate differences in uterine capacity.
   - Genetic markers
   - Physiological measures

Ultrasound measurement of the uterus between 130 and 170 d of age was not adequate for measurement of uterine dimensions (Lents et al., 2014)
• Earliest phenotypic indicator of reproductive longevity.
• Positively associated with component traits of lifetime productivity.
  • Age at first service
  • Conception rate
  • Number of pigs weaned
  • Wean-to-service interval
  • Number of litters produced
  • Longevity
• Collecting age at puberty data is labor intensive and expensive.
• Need for genetic or biological predictors
Pubertal Development

- Genome Wide Association Studies (USMARC).
  - Age at puberty
  - Failure to reach puberty
  - Behavioral anestrus

Translational genomics for improving Sow reproductive longevity.

- UNL, MIZZOU, USMARC
- Funded by USDA-NIFA
- Validation of markers in commercial populations
- Function differences (expressed genes) & interplay with nutrition

<table>
<thead>
<tr>
<th>Trait</th>
<th>Phenotypic variance explained by SNPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at puberty</td>
<td>0.26</td>
</tr>
<tr>
<td>Number of parities</td>
<td>0.19</td>
</tr>
</tbody>
</table>

(Tart et al., 2013; Anim. Genet.)
G31E AVPR1A genotypes influence the success rate of sows generating first two litters

AVPR1A G31E genotypes

1st Parity
- \( GG^{b,c} \)
- \( AG^b \)
- \( AA^c \)

2nd Parity
- \( GG^a \)
- \( AG \)
- \( AA^a \)

\( aP<0.10; \)
\( b,cP<0.05 \)
Expression of AVPR1A in different AVPR1A genotypes

**AA vs. AG**
- **Anterior Pituitary**
  - AA, n=3; AG, n=5

**AA vs. AG**
- **Posterior Pituitary**
  - AA, n=3; AG, n=4

Trenhaile et al., Midwest ASAS, 2014
Functions of AVPR1A in mammals

**Posterior Pituitary**
- Kidney function
  - Water resorption
  - Acid/base balance

**Hypothalamus**
- Fear
- Aggression
- Social recognition
- Maternal behavior
- Sexual behavior
  - Female receptivity (neg. reg.)
  - Pair bonding
  - Mate guarding
Pubertal Development

- **Real-Time RT-PCR**
  - Differences between genotypes, traits or treatments, ect.
  - Specific genes of interest

- **NextGen RNAseq**
  - Whole-genome transcriptome (all the genes that are expressed)
The hypothalamus within the brain receives signals about the environment (e.g., stress, nutrition, appetite, growth) to regulate reproduction through and endocrine mechanisms.

Understanding how these mechanisms work will help us identify what we need to be impacting to improve pubertal development.

Lead us to new solutions to improve management of gilt development for greater productivity.
Economics of using AVPR1A DNA markers

Potential:
\[ \text{Avg}_{NP} + 0.10 \text{ parities} \rightarrow + \$10 \text{ mil/year in US} \]
\[ \text{P3} \rightarrow \text{P4} = + \$77.38 \text{ sow net value} \]

**AVPR1A:**
- Sows with favorable genotype (GG):
  - generate + 0.5 parities/lifetime
  - farrow + 5.1 pigs/lifetime
  - wean + 4.2 pigs/lifetime
- Increase in frequency (0.5 to 0.9) \[ \rightarrow \] + $17 in sow net value

Mote et al. (2006)

Ciobanu, NCERA-57 Symposium, May 20, 2014
Reproductive longevity is influenced by age at puberty and energy input during development.

Effects of energy restriction:
\[ P_{P1} = 0.40 \]
\[ P_{P2} = 0.04 \]
\[ P_{P3} = 0.03 \]

Diet
- ad libitum
- Energy restricted
Objective: examine dietary effects on body composition and gilt development
2 levels of SID lysine (Control, 100%; 85% of control)
3 levels of metabolizable energy
  - Control (100%)
  - 85% of control
  - 115% of control
85LY/85ME diet designed to restrict growth
85LY/115ME and 115LY/85ME designed to alter composition.
Fed from 100 to 260 d of age (n = 1,221 gilts)
Nutrition and Gilt Development

Vallet et al., NPB report, 2014
Nutrition and Gilt Development

• Diet has little impact on standard measures of gilt development.

• Manipulation of gilt development with the diet may be difficult to achieve using conventional approaches.

• The impact that diet during gilt development has on sow productivity (at later parities) and longevity needs to be evaluated.
The size and the direction of the effect of a SNP located on SSC16 (14.4 Mb) is dependent on the energy intake.
The cumulative effect (on age at puberty) of the SNPs, that were affected by the energy intake was marginal and has limited effects on genetic merit of the animals.

The effect of these markers, such as one identified on SSC16 (14.4 Mb), was in a different direction across genotypes and dietary treatments.

It’s not just genetics

Highlights the need for physiological experiments to dissect the functional effects of genetic markers in order to manage the interaction with environment and animal management.
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Vallet et al., NPB# 12209-12210