Production Consequences of Low Birth Weight Pigs

*A comprehensive approach by the K-State Swine Reproductive Physiology, Muscle Biology, and Swine Nutrition & Management labs*

K-State Swine Day - November 19, 2015
Research Progression

Innovation

Refinement

Marketing
Collaboration at K-State

• Our goal is to further the development of management strategies and technologies to improve piglet survivability and ultimate value.
<table>
<thead>
<tr>
<th>Total Born</th>
<th>Survival, %</th>
<th>Number Weaned</th>
<th>Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>86.0</td>
<td>9.46</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>83.5</td>
<td>10.02</td>
<td>.56</td>
</tr>
<tr>
<td>13</td>
<td>81.0</td>
<td>10.53</td>
<td>.51</td>
</tr>
<tr>
<td>14</td>
<td>78.5</td>
<td>10.99</td>
<td>.46</td>
</tr>
<tr>
<td>15</td>
<td>76.0</td>
<td>11.40</td>
<td>.41</td>
</tr>
</tbody>
</table>
The Problem of Extreme Litter-size

Statement of Fact –

Increasing Litter-size (LS) has long been a goal of Pig Breeders and Producers, because it (a) dilutes weaned pig cost and (b) increases number pigs to MKT.

Rapid increases in LS is occurring because of Hyper-prolific sow subsets and a variety of gene markers. It is also clear (and predictable) that more piglets are born with low birth weight. Litter mortality is increasing in parallel to the Increase in Litter-size.

- This has Welfare implications (inadequate access to milk ➔ starvation)
- The Financial benefit is not clear (long-term effects not entirely clear)
- Is Phenomenon same for all Genetics? (NO. Biological Implications Aware)

R. Dean Boyd, 2015
Birth Weight and Mortality

• Large litter sizes =
  Tyler et al., 1990
  Milligan et al., 2002

• Birth weight (BtW) & preweaning mortality:
  Quiniou et al., 2002
  Casellas et al., 2005
  Smith et al., 2007
  Bergstrom, 2011
  Da Silva, 2012
  Panzardi et al., 2013
  Ferrari et al., 2014
  Kohler and Bierman, 2014
Birth Weight & Lifetime Performance

• Poor lifetime growth rate
  – Linear improvement with ↑ BtW up to 4.00 lb
  – Increased days to market
    • 2.2 vs. 4.4 BtW → 230 lb BW = + 14 d
    • 1.8-2.4 vs. 3.9-4.5 lb BtW → 225 lb BW = + 12 d
  – ↓ IGF-1 and fewer, larger muscle fiber numbers

• Poor reproductive performance
  – Small litters, lighter BtW, more BtW variation

Quiniou et al., 2002; Gondret et al., 2005; Peterson, 2008; Corson et al., 2009; Beaulieu et al., 2010; Bergstrom, 2011; Douglas et al., 2013
The Problem of Extreme Litter-size

Small Birth WT Pigs tend to have LO Wean WT. How does Wean WT relate to W-F Growth Rate?

\[ y = 0.0025x^3 - 0.0479x^2 + 0.3156x + 1.0824 \]

IF Facility Time = 160 W-F days:

7.0 lb Weaned Pig, 223 lbs b.w. vs 12.0 lb Pig, 289 lbs

R. Dean Boyd, 2015
Effects of piglet birth weight and gender on the probability of surviving pigs achieving full-value (>220 lb BW) at 180-d of age

Bergstrom, 2011 (Ph.D. dissertation)
Identifying “At-Risk” Birth Weight Pigs

• Is there a BtW threshold for survival across different animal and farm specific influences on mortality?

• Meta-Analysis
  – 4 different farms from 2 different studies
  – 4,068 records of BtW and preweaning survival outcomes

• Mixed effects logistic regression model
  – Random effect of study
  – Piece-wise linear predictor
  – Change point of model determined by comparing model fit for BtW ranging from .7 lb to 5.5 lb based on maximizing the likelihood
Predicted Preweaning Mortality by BtW

Change point in log odds of mortality at 2.45 lb:
Predicted Preweaning Mortality by BtW

19.7% piglets
Conclusion

- Individual BtW is strongly associated with risk of preweaning mortality and relationship is non-linear.

- < 2.45 lb BtW pigs determined to be “at risk” pigs using logistic regression analysis

- Successful interventions may take the form of strategic postnatal intensive care or prenatal efforts to improve musculoskeletal development and BtW

- However, the latter approach of improving BtW not only can improve piglet survivability outcomes, but also contribute to greater lifetime growth and productivity of the pig and profitability to the swine producer.
Fetal Muscle Development

• Muscle Mass Equation

Ultimate Muscle Mass = Muscle Cell Number + Cell Enlargement
# 60-d Fetus Muscle Area Differences

<table>
<thead>
<tr>
<th></th>
<th>Fetus size&lt;sup&gt;1&lt;/sup&gt;</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Medium</td>
<td>Large</td>
<td>P - value</td>
</tr>
<tr>
<td>Whole muscle area, mm&lt;sup&gt;2&lt;/sup&gt;</td>
<td>13%</td>
<td>21%</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Primary fiber number</td>
<td>12%</td>
<td>13%</td>
<td>0.03</td>
</tr>
<tr>
<td>Primary fiber area, μm&lt;sup&gt;2&lt;/sup&gt;</td>
<td>No difference</td>
<td>No difference</td>
<td>0.11</td>
</tr>
<tr>
<td>Secondary per primary</td>
<td>No difference</td>
<td>14%</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

<sup>1</sup>Percent differences compared to small fetus.
90-d Fetus Muscle Area

Size, $P < 0.01$

Cross-sectional area, mm$^2$

<table>
<thead>
<tr>
<th>Fetus Size</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>$&lt; 0.01$</td>
<td>$&lt; 0.01$</td>
<td></td>
</tr>
</tbody>
</table>
Primary Fiber Number

Size, $P = 0.72$

<table>
<thead>
<tr>
<th>Fetus Size</th>
<th>Total number, × 1,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>80</td>
</tr>
<tr>
<td>Medium</td>
<td>75</td>
</tr>
<tr>
<td>Large</td>
<td>85</td>
</tr>
</tbody>
</table>
Primary Fiber Area

Size, $P = 0.64$

Cross-sectional area, $\mu m^2$

<table>
<thead>
<tr>
<th>Fetus Size</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
</table>

K-STATE Research and Extension
Secondary Fiber Number

![Bar chart showing the total number of secondary fibers for different fetus sizes.](chart)

- **Small Fetus Size**: Total number, $\times 100,000 = 16$
- **Medium Fetus Size**: Total number, $\times 100,000 = 18$
- **Large Fetus Size**: Total number, $\times 100,000 = 19$

Size, $P = 0.17$
Secondary Fiber Area

13%  17%  

Size, $P < 0.01$

Cross-sectional area, μm$^2$

<table>
<thead>
<tr>
<th>Fetus Size</th>
<th>0</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>75</td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>Large</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

$P < 0.01$ $P < 0.01$
Small Fetus Muscle Development

- Conception
- Embryonic Stage
- Fetal Stage
- Secondary Myogenesis
- Primary Myogenesis
- Adipogenesis
- Muscle Fiber Hypertrophy

Days: 0 10 20 30 40 50 60 70 80 90 100 110 114

Birth
90-d Fetal Muscle Development

- Secondary fiber hypertrophy responsible for whole muscle differences.
Satellite Cell Number

![Bar chart showing the number of Pax7 positive cells for different fetus sizes.](chart.png)

- **Small**: 80,000 cells
- **Medium**: 100,000 cells
- **Large**: 120,000 cells

Fetus Size: Small, Medium, Large

- **P < 0.03**
- **P < 0.01**

Size, *P* < 0.01
Prenatal growth restriction, altered fetal development, low birth weight, reduced colostrum intake, increased death losses, and fewer full-value pigs.
Day 60 and 95 Allocation of Nutrients

Brain wt. /Liver wt.

95 days

60 days

Fetal Size
Fetal Muscle Development

- Embryonic Stage:
  - Primary Myogenesis

- Fetal Stage:
  - Secondary Myogenesis
  - Muscle Fiber Hypertrophy
  - Adipogenesis

Timeline:
- Days from Conception (0) to Birth (114)
Adaptations of Adipose Tissues

Development of adipose tissue

Drawn from information in the published literature including:
Hausman and Kauffman, 1986; Gondret et al., 2013
Adaptations of Adipose Tissues

Re-drawn from Gondret et al., 2013

Expression of DLK1

- Median wt
- Light wt

71 days  112 days

2 days  Pregnancy  112 days  Neonatal

Damaged
One of the rules of Life:
Those who have get more, those with less get less

Colostrum Consumption
Bigger pigs get more colostrum

- A 3 lb pig needs 36 g more colostrum than a 2.5 lb pig
- A 3 lb pig (on average) consumes 68 g more colostrum
Immunocrit values and performance traits
Vallet et al., 2015
Postnatal growth sorted on immunocrit status

<table>
<thead>
<tr>
<th>Age, days</th>
<th>Weight, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>80</td>
<td>140</td>
</tr>
<tr>
<td>100</td>
<td>160</td>
</tr>
</tbody>
</table>

- Male low
- Male high
- Female low
- Female high
Reproduction and immunocrit

- More immunoglobulins
- Earlier age at puberty
- ↑ litter size
- ↑ pre-weaning growth

Inter-related Indicators

- Birth wt
- Brain/liver wt ratio
- Colostrum consumed
- Blood immunoglobulins (immunocrit)

Vallet et al., 2015
Gestation programming affects

→ Neonatal period → Growth to market wt → Carcass

DAMAGED PIGS

Correctable?/Adaptable?