Milk production and mammary development in swine

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OUTLINE:

✓ Milk yield:
  - why is it important?
  - factors of variations

✓ Mammary development:
  - why
  - when
  - can we alter it?
OUTLINE:

✓ Hormonal control of mammogenesis
  ➢ prepuberty
  ➢ gestation

✓ Nutritional effects on mammogenesis
  ➢ prepuberty
  ➢ gestation

✓ Body condition & mammary development
Goal in a maternity: Wean as many piglets of the greatest weight possible.
Milk: Main energy source for piglets
The sow is not producing enough milk to sustain maximal piglet growth.

I would prefer milk!
### Milk yield between 1971 and 1998

<table>
<thead>
<tr>
<th>Milk yield (kg/day)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2</td>
<td>Elsley (1971)</td>
</tr>
<tr>
<td>7.1</td>
<td>Noblet &amp; Étienne (1986)</td>
</tr>
<tr>
<td>8.3</td>
<td>Schoenherr et al. (1989)</td>
</tr>
<tr>
<td>8.6</td>
<td>King et al. (1993)</td>
</tr>
<tr>
<td>9.9</td>
<td>King et al. (1996)</td>
</tr>
<tr>
<td>8.7</td>
<td>Toner et al. (1996)</td>
</tr>
<tr>
<td>10.3</td>
<td>Sauber et al. (1996)</td>
</tr>
<tr>
<td>11.6</td>
<td>King &amp; Eason (1998)</td>
</tr>
</tbody>
</table>

- Stable thereafter
But...

✓ in litter size has \( \uparrow \) the amount of milk ingested per piglet

hyperprolificity is a new problem
How can we increase sow milk yield?
Milk production (genetics)

✓ heritability of 0.20 to 0.28

✓ breed effect:
  Large White > Pietrain
  50% Meishan > Large White

✓ 13% of Yorkshire gilts have at least 1 non-functional teat (inverted, blind...) at 100 kg BW

heritability of 0.29
selection possible
Multiparous (+ 25%) > primiparous

Milk yield:
- increases from parity 1 to 2
- is greatest in parities 2 to 4,
- decreases thereafter

Amount of milk/piglet:
- lowest for parity 1 (925 g/d)
- highest for parities 2-4 (1.02 g/d)
Milk production (litter size)

- milk yield with litter size, but
- amount of milk ingested/piglet
  - 4 vs 12 piglets: 1.0 vs 0.7 kg/day
  - 6 vs 14 piglets: 1.6 vs 1.1 kg/day
Milk production (stage of lactation)

- Quadratically, maximum days 15-21

Milk composition varies:
- Protein and fat ↓ as lactation advances
- Lactose ↑ as lactation advances
Milk production (suckling interval)

✓ 35, 50, 70 or 100 min: similar amount of milk produced per suckling

➢ milk synthesis already maximal after 35 minutes

Must attempt to reduce suckling interval to 35 min
Milk production (environment)

- continuous high noise (ex: ventilator)
  - milk intake/piglet/suckling via perturbation of normal suckling rythm

- photoperiod (16 vs 8 h light/day)
  - suckling intervals
  - piglet weight gain

- ambient temperature
  - heat stress milk yield
Milk production (nutrition)

- **protein restriction:** ↓ piglet weight gain
  - lysine and leucine: 2 most limiting amino acids → requirements must be met

- **energy:** similar milk yield
  - depends on body condition
  - ↓ if restriction over 3 successive parities

*Must maximize sow feed intake in lactation!*
Milk production (hormones)

✓ Somatotropin (GH) injections:
  ➢ inconsistent results on milk yield
  ➢ affects metabolism
  ➢ more efficient use of dietary proteins

Sow are not like cows!
Milk production (hormones)

- Inhibition of prolactin: affects initiation and maintenance of milk production

- Inhibition of prepartum peak

  piglets die...

  because no initiation of lactation
Milk production (hormones)

✓ inhibition of prolactin:
affects initiation and maintenance of milk production
Milk production (hormones)

✓ exogenous prolactin in lactation:
  ➢ no effect on milk yield
  ➢ no effect on composition of mammary glands at the end of lactation

BUT

➢ prolactin receptors already saturated in CTL sows
Mammary gland development: WHY?
Main factor limiting milk yield

# of milk-secreting cells present in mammary tissue at the onset of lactation

Head et al. (1991)
Mammary Gland Development

✓ Correlation between the size of a mammary gland and its milk yield (i.e. weight of piglet nursing it)

✓ Concluded that replacement gilts should be managed so as to enhance their mammary development...
Mammary Development

- When?
- Can we alter it?
Mammary development: anatomy

Structure of sow’s udder

- Alveolus
- Parenchyma
- Extraparenchyma
- Lactiferous ducts
- Teat
Ontogenesis of mammary development

At birth:
- mainly stromal tissue
- poorly developed duct system

3 stages of rapid mammary accretion:
- 1- prepuberty: 90 days onward
- 2- last third of gestation
- 3- lactation

during those periods there is a possible impact of hormones and nutrition
Mammary development: prepuberty

Sorensen et al. (2002)
Mammary development: puberty

- extraparenchyma: 1286 vs 1528 g
- parenchyma: 376 vs 249 g
- important duct system

Essential role of estrogens
Mammary development: gestation

Sorensen et al. (2002)
<table>
<thead>
<tr>
<th>Primiparous</th>
<th>Day of lactation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Surface area (cm²)</td>
<td>47.2</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>381</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>39.4</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>55.1</td>
</tr>
<tr>
<td>DNA (%)</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Kim et al. (1999)
Mammary involution at weaning

✓ Essential process: rapid regression within 7-10 days post-weaning

❖ more than 2/3 ↓ in weight and in parenchymal DNA

❖ unused glands in lactation show no further ↓ after weaning
Mammary involution in lactation

✓ Rapid regression of unused teats in early lactation (7-10 days)
  ✷ mammary tissue ↓ by 2/3
✓ Reversible within 24 h postpartum:
  ✷ but milk yield remains lower...
✓ Irreversible after 3 days: no X-fostering
Mammary development

✓ It was noticed that teats which are nursed are larger after post-weaning involution than unused teats... (Ford et al. 2003)
Which leads to the question...

What is the possible impact of the non-use of a teat in 1\textsuperscript{st} lactation on its milk yield in 2\textsuperscript{nd} lactation?
Teat use project 1

Blocking the same teats or different teats during the 1st and 2nd lactation
Teat use project 1

Lactation 1

Lactation 2 - SAME

Lactation 2 - DIFF

or

average of 14 functional teats

6 piglets per litter
Teat use project 1

End of 1st lactation (tape removed on d 7)
## Teat use project 1

### Piglet weight (kg):

<table>
<thead>
<tr>
<th></th>
<th>SAME</th>
<th>DIFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>d 2</td>
<td>1.65</td>
<td>1.57</td>
</tr>
<tr>
<td>d 4</td>
<td>2.08</td>
<td>1.93</td>
</tr>
<tr>
<td>d 7</td>
<td>2.92</td>
<td>2.71</td>
</tr>
<tr>
<td>d 14</td>
<td>5.39</td>
<td>4.97</td>
</tr>
<tr>
<td>d 21</td>
<td>6.73</td>
<td>6.29</td>
</tr>
<tr>
<td>d 35</td>
<td>10.83</td>
<td>10.28</td>
</tr>
<tr>
<td>d 56</td>
<td>22.72</td>
<td>21.60</td>
</tr>
</tbody>
</table>

Piglets weigh 1.12 kg more on day 56!
## Teat use project 1

<table>
<thead>
<tr>
<th>MAMMARY GLAND</th>
<th>SAME</th>
<th>DIFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraparenchyma (g)</td>
<td>692.5</td>
<td>714.3</td>
</tr>
<tr>
<td>Parenchyma (g/teat)</td>
<td><strong>800.4</strong>*</td>
<td>641.6</td>
</tr>
<tr>
<td>-fat (%)</td>
<td>37.9</td>
<td>37.6</td>
</tr>
<tr>
<td>-protein (%)</td>
<td>52.0</td>
<td>52.9</td>
</tr>
<tr>
<td>-DNA (g/teat)</td>
<td><strong>1.8</strong>*</td>
<td>1.4</td>
</tr>
<tr>
<td>-RNA (g/teat)</td>
<td><strong>4.0</strong>*</td>
<td>3.3</td>
</tr>
</tbody>
</table>
What is the minimum time that a teat must be suckled in first lactation to avoid decreasing its milk yield in 2nd lactation?
Project at Sherbrooke AAFC:

- Primiparous sows were divided in 3 groups according to lactation length in 1st parity:
  - 2 days, 7 days, or 21 days

- 2nd lactation: 21 days

- Litters uniformized to 12 piglets for 12 teats (surplus sealed) in lactations 1 & 2

- Piglets weighed weekly in lactation 2
In parity 2: no difference in weight gain of suckling piglets between the 3 treatment groups.

Suckling a teat for 2 d during the first lactation is sufficient to ensure enough mammary development so that the next lactation performance is not hindered.
Endocrine control of mammogenesis

Estrogens ↔ Prolactin
Mammary development (estrogens)

✓ Role at puberty stated earlier

✓ Role in gestation:
  ➢ estrogens of foetal origin
  ➢ positive correlation between [estrogen] in blood and DNA in mammary tissue of sows on day 110 of gestation
  ➢ authors concluded that:
    ❖ estrogens have a positive effect on mammary development in late gestation
Mammary development (prolactin)

- inhibition from days 70-110 of gestation
## Inhibition of prolactin in gestation

<table>
<thead>
<tr>
<th></th>
<th>CTL</th>
<th>50-69</th>
<th>70-89</th>
<th>90-110</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half-gland (g)</td>
<td>4792</td>
<td>4138</td>
<td>4214</td>
<td>3350</td>
</tr>
<tr>
<td>Extraparenchyma (g)</td>
<td>1463</td>
<td>1476</td>
<td>1399</td>
<td>1300</td>
</tr>
<tr>
<td>Parenchyma (g)</td>
<td>1702</td>
<td>1448</td>
<td>1468</td>
<td>919</td>
</tr>
<tr>
<td>-Fat (%)</td>
<td>55.2</td>
<td>56.5</td>
<td>59.7</td>
<td>67.6</td>
</tr>
<tr>
<td>-Protein (%)</td>
<td>41.6</td>
<td>40.2</td>
<td>39.2</td>
<td>31.7</td>
</tr>
<tr>
<td>-DNA (mg/g)</td>
<td>11.2</td>
<td>10.5</td>
<td>10.8</td>
<td>10.8</td>
</tr>
<tr>
<td>-Protein/DNA</td>
<td>37.7</td>
<td>38.8</td>
<td>37.3</td>
<td>30.0</td>
</tr>
</tbody>
</table>

Farmer et al. (2003)
Exogenous PRL in gilts

McLaughlin et al. (1997):
there is apparent mammary development following injections of 2 mg/d of rpPRL for 28 d, starting at 75 kg
Injections of pPRL for 29 d (as of 75 kg)

✓ effects on mammary development

<table>
<thead>
<tr>
<th>Slaughter on d 183:</th>
<th>CTL</th>
<th>4 mg</th>
<th>8 mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraparenchyma (g)</td>
<td>669</td>
<td>648</td>
<td>762</td>
</tr>
<tr>
<td>Parenchyma (g)</td>
<td>200</td>
<td>432</td>
<td>364</td>
</tr>
<tr>
<td>- Fat (%)</td>
<td>92.0</td>
<td>82.2</td>
<td>84.2</td>
</tr>
<tr>
<td>- Protein (%)</td>
<td>7.6</td>
<td>17.5</td>
<td>17.6</td>
</tr>
<tr>
<td>- DNA (mg/g)</td>
<td>2.3</td>
<td>6.0</td>
<td>6.1</td>
</tr>
</tbody>
</table>

Farmer et al. (2005)
exogenous prolactin

↑ number

mammary cells
Mammary development (prolactin)

- Prolactin in late-gestation (days 90-110) using a pharmacological agent (VanKlompenberg et al. 2013)
  - Alveolar volume of mammary glands (where milk is secreted)
  - Milk yield by 25% on day 14
  - Weight of piglets by 21% during lactation
Mammary development (Nutrition)

✓ Nutrition of prepubertal gilts

✓ Nutrition in gestation

✓ Nutrition in lactation
Mammary dev.: Prepubertal nutrition

Feed restriction

- 26% restriction days 28-90 (period 1) or days 90-170 (period 2)
  - period 1: no effect on mammary development
  - period 2: ad lib mammary tissue
  - ad lib DNA content

Sorensen et al. (2006)
## 20% feed restriction d 90-202

<table>
<thead>
<tr>
<th></th>
<th>CTL</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraparenchyma (g)</td>
<td>1518</td>
<td>881</td>
</tr>
<tr>
<td>Parenchyma (g)</td>
<td>345</td>
<td>254</td>
</tr>
<tr>
<td>- Fat (%)</td>
<td>93.5</td>
<td>93.3</td>
</tr>
<tr>
<td>- Protein (%)</td>
<td>5.8</td>
<td>6.5</td>
</tr>
<tr>
<td>- DNA (mg/g)</td>
<td>1.2</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Farmer et al. (2004)
Protein restriction:

- 14.4% vs 18.7% CP (0.7 vs 1.0% lys) from 90-202 days of age:
  - no effect on mammogenesis

Farmer et al. (2004)
Supplementation with flax

- 10% flaxseed (oil & lignans: estrogenic)
- 88-212 days of age:
  - expected effects on fatty acid profile
  - no effects on mammogenesis at 212 d

Farmer et al. (2007)
Mammary dev.: Prepubertal nutrition

✓ Addition of a phytoestrogen

- standard soya diet (CTL) or
- standard soya diet + 2.3 g/d genistein from 90-183 days of age:
  ✷ phytoestrogens in blood
  ✷ 44% parenchymal DNA (cell #)

Farmer et al. (2010)
Mammary dev.: nutrition in gestation

- **energy intake last third** (Weldon et al. 1991):
  - 44 vs 24 MJ ME/d: ↓ parenchyma ↓ DNA

- **protein intake last third**:
  - 330 vs 216 g CP/d: no effect
  - 4, 8, 16 g lysine/d: no effect
  - but ↑ milk yield in following lactation with 16 g/d  

(Weldon et al. 1991; Kusina et al. 1999)
Mammary dev.: nutrition in gestation

✓ Supplementation with flax
  ➢ 10% flaxseed from d 63 of gestation to d 21 lactation

  ➥ FI adjusted so similar protein & energy intakes in gestation
  ➥ fed ad lib in lactation
    ▪ effect on mammogenesis of offspring at puberty
      ▪ 31% ↑ parenchymal mass
Mammary dev.: nutrition in lactation

- Energy intake
  - 14.6 vs 12.6 MJ ME/kg of diet:
    - mammary weight of nursed glands
    - mammary DNA
    - mammary protein

Kim et al. (1999)
Mammary dev.: nutrition in lactation

Protein intake

- 16.2 vs 8.0 g lysine/kg of diet:
  - mammary weight of nursed glands
  - mammary DNA
  - mammary protein

Kim et al. (1999)
Mammary dev.: nutrition in lactation

✓ Litter size \( \uparrow \) protein requirements

➢ for each additional piglet starting with 6 piglets/litter:

❖ should \( \uparrow \) lysine intake by 0.96 g/day

Kim et al. (1999)
Mammary dev.: body condition

Change in body condition:

- **backfat (36 vs 25 mm):**
  - mammary development at the end of gestation
    - $\frac{1}{4}$ of DNA present
    - $\frac{1}{2}$ of alveolar cells present
  - milk yield (7 vs 9 L/d) in next lactation

Head & Williams 1991-95
Mammary dev.: body condition

✓ Change in body condition:

- what about body conditions seen commercially?
Project 1: Backfat end of gestation

HBF
MBF
LBF

BF (mm)

21-26 mm
17-19 mm
12-15 mm

22,0
20,6
19,3
18,9
18,0
17,2
17,7
17,6
17,8
16,7
16,3
15,9
15,8
15,5
14,5
14,0
16,0
18,0
20,0
22,0
24,0

d 1
d 30
d 50
d 70
d 100
d 109
## Project 1: Backfat end of gestation

<table>
<thead>
<tr>
<th>Slaughter d 110</th>
<th>LBF</th>
<th>MBF</th>
<th>HBF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraparenchyma (g)</td>
<td>1075</td>
<td>1360</td>
<td>1578</td>
</tr>
<tr>
<td>Parenchyma (g)</td>
<td>1059</td>
<td>1370</td>
<td>1444</td>
</tr>
<tr>
<td>- DM (%)</td>
<td>38.4</td>
<td>40.8</td>
<td>42.5</td>
</tr>
<tr>
<td>- Fat (%)</td>
<td>62.8</td>
<td>65.9</td>
<td>68.2</td>
</tr>
<tr>
<td>- Protein (%)</td>
<td>35.1</td>
<td>31.3</td>
<td>29.4</td>
</tr>
<tr>
<td>- DNA (mg/g)</td>
<td>10.9</td>
<td>10.0</td>
<td>9.0</td>
</tr>
</tbody>
</table>

Farmer et al. 2015
Backfat at mating maintained

**BF (mm)**
- HBF (22-26 mm)
- MBF (17-20 mm)
- LBF (12-15 mm)
## Backfat at mating maintained

<table>
<thead>
<tr>
<th>Slaughter d 110</th>
<th>LBF</th>
<th>MBF</th>
<th>HBF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraparenchyma (g)</td>
<td>1259</td>
<td>1403</td>
<td>1951</td>
</tr>
<tr>
<td>Parenchyma (g)</td>
<td>1238</td>
<td>1270</td>
<td>1341</td>
</tr>
<tr>
<td>- DM (%)</td>
<td>36.0</td>
<td>40.4</td>
<td>43.4</td>
</tr>
<tr>
<td>- Fat (%)</td>
<td>60.5</td>
<td>65.2</td>
<td>68.9</td>
</tr>
<tr>
<td>- Protein (%)</td>
<td>35.1</td>
<td>31.3</td>
<td>29.4</td>
</tr>
<tr>
<td>- DNA (mg/g)</td>
<td>11.06</td>
<td>9.49</td>
<td>8.39</td>
</tr>
</tbody>
</table>

Farmer et al. 2016
Concluding remarks

- Sow milk yield has increased over the years but not the amount of milk ingested/piglet.

- Mammary development is important and can be altered by both endocrine and nutritional factors.

- Body condition of gilts affects mammary development in late gestation.
Concluding remarks

• Factors that enhance mammogenesis:
  - **in utero:** feeding flaxseed
  - **prepuberty:** no feed restriction after 90 d
    - exogenous prolactin
    - phytoestrogens
  - **end gestation:** lysine intake?
    - backfat thickness (> 16 mm)
  - **lactation:** protein intake
  - energy intake
Concluding remarks

- Management of sows in their 1st lactation is important for their performance in 2nd lactation.
Thank you!
Editor of a book published in 2015
Recent update of knowledge on sows
Available on line from Wageningen Academic Press