Improving sow lactational performance

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OUTLINE:

✓ Milk yield:
  ➢ why is it important?
  ➢ factors of variation

✓ Mammary development:
  ➢ why?
  ➢ when?
  ➢ how?
  ➢ mammary involution
  ➢ 2 projects on effects of teat use in parity
    1 on mammary development in parity 2
  ➢ can we stimulate it?
OUTLINE:

✓ Hormonal control of mammary development
  ➢ estrogens
  ➢ prolactin

✓ Nutritional effects on mammary development
  ➢ prepuberty
  ➢ gestation
  ➢ lactation

✓ Body condition and 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>Scientific 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>
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<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** ↓ **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 0.27

✓ 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
Milk production (parity)

✓ 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 (suckling interval)

✓ suckling every 35 versus 70 min over a 24 h period:

- amount of milk ingested by 27%
- weight gain by 44%

- difficult to do in a commercial situation…
Milk production (environment)

- Continuous high noise (ex: ventilator)
  - Milk intake/piglet/suckling via perturbation of normal suckling rhythm

- 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 composition (nutrition)

- Amino acid content not affected by sow nutrition (unless feed synthetic amino acids...$$)

- Milk fat varies with energy intake
  - $\uparrow$ energy $\uparrow$ milk fat
Milk production (hormones)

✓ Inhibition of prolactin: affects initiation 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

![Graph showing weight gain over days](image)
Mammary gland development: WHY?
Main factor limiting milk yield

# of secretory cells present in mammary tissue at the onset of lactation

Head et al. (1991)
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
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
Ontogenesis of mammary development

Sorensen et al. (2002)
Mammary development: puberty

✓ extraparenchyma ↓: 1286 vs 1528 g
✓ parenchyma ↑: 376 vs 249 g
✓ important duct system

Essential role of estrogens
Ontogenesis of mammary development

Sorensen et al. (2002)
## Mammary gland composition

<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 at weaning

**Days post-weaning**

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface area (cm²)</strong></td>
<td>59.7</td>
<td>43.9</td>
<td>47.2</td>
<td>38.4</td>
<td>31.4</td>
<td>26.8</td>
</tr>
<tr>
<td><strong>Weight (g)</strong></td>
<td>486</td>
<td>314</td>
<td>304</td>
<td>248</td>
<td>202</td>
<td>152</td>
</tr>
<tr>
<td><strong>DNA (mg/gland)</strong></td>
<td>839</td>
<td>489</td>
<td>474</td>
<td>461</td>
<td>329</td>
<td>278</td>
</tr>
<tr>
<td><strong>Protein (g/gland)</strong></td>
<td>56.1</td>
<td>36.2</td>
<td>35.0</td>
<td>28.6</td>
<td>23.3</td>
<td>17.5</td>
</tr>
<tr>
<td><strong>Fat (g/gland)</strong></td>
<td>45.4</td>
<td>44.5</td>
<td>48.3</td>
<td>31.7</td>
<td>26.1</td>
<td>20.1</td>
</tr>
</tbody>
</table>

*Ford et al. (2003)*
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
It was noticed that teats which are suckled are larger after post-weaning involution than unused teats...  (Ford et al. 2003)
Leading 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?
Project 1: Teat use

Blocking the same teats or different teats during the 1\textsuperscript{st} and 2\textsuperscript{nd} lactation
Project 1: Teat use

Lactation 1

Lactation 2 - SAME

or

Lactation 2 - DIFF

average of 14 functional teats

6 piglets per litter
Project 1: Teat use

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

<table>
<thead>
<tr>
<th>Piglet weight (kg):</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
<table>
<thead>
<tr>
<th>Weight gain (kg):</th>
<th>SAME</th>
<th>DIFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>d 2 to 4</td>
<td>0.43*</td>
<td>0.35</td>
</tr>
<tr>
<td>d 4 to 7</td>
<td>0.84</td>
<td>0.78</td>
</tr>
<tr>
<td>d 7 to 14</td>
<td>2.47*</td>
<td>2.26</td>
</tr>
<tr>
<td>Lactation: d 2 to 14</td>
<td>3.74*</td>
<td>3.40</td>
</tr>
</tbody>
</table>
## Project 1: Teat use

<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>800.4*</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>1.8*</td>
<td>1.4</td>
</tr>
<tr>
<td>-RNA (g/teat)</td>
<td>4.0*</td>
<td>3.3</td>
</tr>
</tbody>
</table>
Next question:

What is the minimum time that a teat must be suckled in 1\(^{st}\) lactation to avoid decreasing its milk yield in 2\(^{nd}\) lactation?
Project 2: Teat use

Materials and methods:

- primiparous sows were divided in 3 groups according to lactation length in 1\textsuperscript{st} parity:
  - 2 days (2D, n=20)
  - 7 days (7D, n=20)
  - 21 days (21D, n=21)

- 2\textsuperscript{nd} lactation: 21 days

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

- piglets weighed weekly in lactation 2
## Project 2: Teat use

<table>
<thead>
<tr>
<th>Piglets (kg)</th>
<th>2 D</th>
<th>7 D</th>
<th>21 D</th>
</tr>
</thead>
<tbody>
<tr>
<td>- d 2</td>
<td>1.8</td>
<td>1.8</td>
<td>1.9</td>
</tr>
<tr>
<td>- d 7</td>
<td>3.0</td>
<td>2.9</td>
<td>3.0</td>
</tr>
<tr>
<td>- d 14</td>
<td>5.0</td>
<td>4.8</td>
<td>4.9</td>
</tr>
<tr>
<td>- d 21 (weaning)</td>
<td>6.8</td>
<td>6.6</td>
<td>6.7</td>
</tr>
<tr>
<td>- d 31</td>
<td>8.7</td>
<td>8.5</td>
<td>8.7</td>
</tr>
<tr>
<td>- d 56</td>
<td>23.2</td>
<td>23.1</td>
<td>23.5</td>
</tr>
</tbody>
</table>
Project 2: Teat use

- 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 (estrogen)

✓ Role at puberty (stated earlier)

✓ Role in gestation
  - estrogens of fetal 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)
McLaughlin et al. (1997):

- there is apparent mammary development following injections of rpPRL for 28 days, 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)
Impact on future milk yield?
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)

นม milk yield by 25% on day 14

นม weight of piglets by 21% during lactation

นม no change in milk composition
Mammary development (Nutrition)

- Nutrition of prepubertal gilts
- Nutrition in gestation
- Nutrition in lactation
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)
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 mammogogenesis at 212 d

Farmer et al. (2007)
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

- **Lysine intake in late gestation**
  - 20.6 vs. 14.7 g/d lysine (all other amino acids met NRC recommendations)
  - from 90 days of gestation until farrowing
    - ADG of piglets next lactation (248 vs. 228 g/d)
    - may be due to improved mammary development OR...
      - to numerically greater birth weights (Che et al. 2019)
Supplementation with flax

- 10% flaxseed from d 63 of gestation to d 21 lactation
- FI adjusted in gestation so similar protein & energy
- fed ad lib in lactation
  - effect on mammary development in offspring at puberty
  - 31% parenchymal mass
Mammary dev.: Nutrition in lactation

☑️ Energy intake

ราว 14.6 วิ่ง 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)
Change in body condition:

- backfat (36 vs 25 mm):
  - mammary development at the end of gestation
    - ¼ of DNA present
    - ½ of alveolar cells present

- milk yield (7 vs 9 L/d) in next lactation

Head & Williams 1991-95
Change in body condition:

- what about body conditions seen commercially?

2 projects: comparing low, medium and high backfats either at mating or at the end of gestation
Project 1: Backfat end of gestation

<table>
<thead>
<tr>
<th>Days of gestation</th>
<th>HBF</th>
<th>MBF</th>
<th>LBF</th>
</tr>
</thead>
<tbody>
<tr>
<td>d 1</td>
<td>16.2</td>
<td>16.3</td>
<td>16.3</td>
</tr>
<tr>
<td>d 30</td>
<td>16.7</td>
<td>17.2</td>
<td>15.9</td>
</tr>
<tr>
<td>d 50</td>
<td>18.0</td>
<td>17.7</td>
<td>15.8</td>
</tr>
<tr>
<td>d 70</td>
<td>18.9</td>
<td>17.6</td>
<td>15.5</td>
</tr>
<tr>
<td>d 100</td>
<td>19.3</td>
<td>17.8</td>
<td>14.5</td>
</tr>
<tr>
<td>d 109</td>
<td>20.6</td>
<td></td>
<td>14.0</td>
</tr>
</tbody>
</table>
# 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)

Days of gestation

- 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>35.0</td>
<td>31.1</td>
<td>27.7</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 per piglet.
- Mammary development is important and can be altered by hormonal and nutritional factors.
- Body condition (i.e. gestation feeding) of gilts affects mammary development in late gestation.
- Nutrient intake in lactation is important to maximize mammary development.
Concluding remarks

• Factors that enhance mammogenesis:

  ➢ in utero: feeding flaxseed

  ➢ prepuberty: no feed restriction after 90 d exogenous prolactin feeding phytoestrogens

  ➢ end gestation: ➢ lysine intake ? ➢ prolactin backfat thickness (> 16 mm)
Concluding remarks

- Factors that enhance mammogenesis:
  - lactation:
    - energy intake
    - protein intake
  - feed intake

There is still much to be learned...
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 online from Wageningen Academic Press