An integrated low protein diet concept to increase nutrient efficiency and minimize the environmental impact of pig production

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Evonik Nutrition & Care GmbH
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- Introduction
- Development of feeding concepts for swine
- Effects of lowering dietary CP content on pig performance and carcass quality
- Integrated approach – synergistic effect of low CP with probiotics and fibers
- Application of low CP diet to mitigate environmental impact of pig production
- Take home messages
**Introduction:** current challenges of commercial pig production

**Goal:** profitable but in a sustainable way

**Climate change**
- Environmental pollution

**Food demand**
- Population growth

**Pig production**

**Food Quality / Safety**
- Consumer demand

**Animal health / welfare**
- Sub-optimal immune status (AGPs-ban)

**Food demand**
- Population growth

**Food Quality / Safety**
- Consumer demand

**Introduction**
Introduction: A growing demand for pork and other meat production

Introduction

To produce more animal feed, a linear increase in the need of croplands and water.

FAO (2017)

OECD-FAO AGRICULTURAL OUTLOOK 2017-2026 © OECD/FAO 2017
Current planetary boundaries: increased regulation toward minimizing N/P pollution

Contribution from livestock production
- N in manure can turn into \( \text{NH}_3 \)
- \( \text{NH}_3 \) emission \( \rightarrow \) air pollution (PM2.5)
- Livestock ~ 2/3 of \( \text{NH}_3 \) from agriculture

GHG emission target (2020 vs. 1990)
- EU: 20% reduction
- Germany: 40% (1,252 mil. ton \( \text{CO}_2 \text{e} \))
  - New fertilizer ordinance (2017)
- Smithfield: 25% (4 mil. ton \( \text{CO}_2 \text{e} \) equiv.)

- Low CP-PP diets (minimize N output; improve efficiency)
- Increased use of alternative / local feedstuffs (insect meal, DDGS,…)
- Genetic potentials (breeding)

Rockstroem et al. (2009)
Not all crude protein and amino acids in ingredients are digestible

Crude Protein = N x 6.25

Ingredients CP and AA digestibilities are variable.

Animals need amino acids for body protein synthesis

Source: Evonik review

Development of feeding concepts for swine
Diets based on grains and SBM results into excess level of CP and AA

21.9% CP (Barley-corn-SBM diet for 40-70 kg pigs)

15.7% CP (Barley-corn-SBM-4 AA diet for 40-70 kg pigs)

- Pigs need balanced diets containing adequate levels of all nutrients including AA (rather than CP)
- Protein synthesis is “all or nothing”.
- Lys is the first limiting AA in typical pig diets (followed by Thr, Met and Trp, Val and Ile)

Development of feeding concepts for swine
Development of feeding concepts for swine

- **< 1950**: Fecal dig. CP, total AA, DE
- **1982**: CP, ileal (AID, True) AA, IP, DE, ME
- **1992**: CP, SID AA, IP, ME, NE
- **2000**: SID AA, IP, NE - Low CP diet
- **> 2010**: Dynamic AA ratio, Precision feeding

Feed-grade amino acids:
- Val
- Ile
- Trp
- Thr
- Lys
- Met

Gross Energy (100 %)
- DE:GE 82%
- Fecal Energy (18%)

Digestible Energy (82%)
- ME:DE 96%
- Urine (3%)
- Methane (0.3%)

Metabolisable Energy (78.7%)
- NE:ME 74%
- Net Energy (58.2%)

Heat production (20.5%)

Improved efficiency, precision and flexibility and consistent performance
Reducing dietary CP did not compromise ADG and FCR of 6-28 kg pigs (Overview)

10 trial results (1998-2014); CP reduction: 2 to 7%-points

Effect of lowering dietary CP on pig performance and carcass
Reducing dietary CP did not compromise ADG and FCR of 20-72 kg pigs (Overview)

11 trial results (1998-2011); CP reduction: 2 to 6%-points

Effect of lowering dietary CP on pig performance and carcass
Reducing dietary CP did not compromise backfat and dressing % of finishing pigs

9 trial results (1995-2013); CP reduction: 2 to 4.5%-points

Effect of lowering dietary CP on pig performance and carcass
Amino acids deficiency reduced performance of 20-49 kg pigs (35-d)

<table>
<thead>
<tr>
<th>CP, %*</th>
<th>NE, MJ/kg</th>
<th>Total Lys, %</th>
<th>4 EAA level</th>
<th>EAA added</th>
<th>Trp:Lys, %</th>
<th>Val:Lys, %</th>
<th>Ile:Lys, %</th>
<th>Lys:CP, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.3</td>
<td>9.81</td>
<td>0.79</td>
<td>Adeq.</td>
<td>-</td>
<td>20</td>
<td>89</td>
<td>78</td>
<td>4.8</td>
</tr>
<tr>
<td>12.2</td>
<td>9.92</td>
<td>0.76</td>
<td>Adeq.</td>
<td>4</td>
<td>18</td>
<td>67</td>
<td>54</td>
<td>6.2</td>
</tr>
<tr>
<td>10.1</td>
<td>9.96</td>
<td>0.73</td>
<td>Adeq.</td>
<td>4</td>
<td>15</td>
<td>59</td>
<td>44</td>
<td>7.2</td>
</tr>
</tbody>
</table>

* Lowering CP by replacing of SBM with free AA.

Figueroa et al. (2002)

Effect of lowering dietary CP on pig performance and carcass
Low CP diet is advantageous for pigs raised under hot climatic condition (68-95 kg pigs; 30-d)

<table>
<thead>
<tr>
<th>CP, %</th>
<th>Temp, °C</th>
<th>ME, MJ/kg</th>
<th>SID Lys, %</th>
<th>EAA level</th>
<th>EAA added</th>
<th>SID Lys:CP, %</th>
<th>EB, mEq/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.2</td>
<td>31</td>
<td>13.6</td>
<td>0.75</td>
<td>Adeq.</td>
<td>2</td>
<td>4.6</td>
<td>158</td>
</tr>
<tr>
<td>13.7</td>
<td>31</td>
<td>13.6</td>
<td>0.75</td>
<td>Adeq.</td>
<td>4</td>
<td>5.5</td>
<td>158</td>
</tr>
</tbody>
</table>

*R Electrolyte balance = (Na + K - Cl); SBM contains 2 to 2.2% of K.

**Room temperature, 31°C**

<table>
<thead>
<tr>
<th></th>
<th>16.2% CP</th>
<th>13.7% CP</th>
</tr>
</thead>
</table>
| Feed intake, kg/d     | 2.36
| ADG, kg/d             | 0.83
| FCR, g/g              | 2.82     | 2.75     |
| Dressing, %           | 80.0     | 80.4     |
| Carcass lean, %       | 61.4     | 59.6     |
| Backfat, cm           | 1.36     | 1.60     |

*a,b* Within a row, values with different letters are different (*P* < 0.05).

Rodrigues et al. (2012)
Reasons for the inconsistent results with feeding pig low CP-AA diets and suggested solutions

**Reasons:**

- Diet formulation on the basis of total AA content
- Deficiency of the next limiting AA (Val and Ile)
- Deficiency of NEAA or N (> 5 %-pt CP)
- DE or ME often lead to a greater backfat thickness

**Solutions:**

- Rapid analysis of ingredients (CP, AA) and convert to SID AA (AMINONIR; AMINODat 5.0)
- Recommendations for SID AA and IP concept (AMINODat 5.0; NRC, 2012; Breeder Recommendation)
- SID Lys:CP <6.9% (7.4% total Lys:CP) essential N:total N 48:100 (Heger et al. 1998)
- NE based feed formulation
  - Rapid analysis of energy (AMINONRG)

Effect of lowering dietary CP on pig performance and carcass
Lowering dietary CP reduces hindgut ammonia concentration and diarrhea incidence in piglets

Effect of diet CP content on ammonia and pH in cecum

Reducing dietary CP from 24 to 18% (2 wk post-weaning) reduces post-weaning diarrhea

Infected = challenged with an enterotoxigenic strain of *E. coli*

I x CP interaction P<0.05

Integrative approach – synergistic effect of low CP with probiotics and fibers
Synergy of LCP diet with a probiotic on ADG of *E. coli* challenged piglets (d 7-12 post-weaning)

Effect for CP: $P = 0.007$
Effect for additives = 0.086

**CON** = no additive; **AGP** = in-feed antibiotics; **PRO** = probiotics (*E. coli* strains)

Bhandari et al. (2010)

*Integrated approach – synergistic effect of low CP with probiotics and fibers*
A low CP diet with probiotics had positive effects on diarrhea incidence and ADG of weaned pigs (d 0-21 post-weaning)

\[ \text{HPa} = 20\% \text{ CP+ antibiotic (\textit{lincomycin + spectinomycin; Zoetis})} \]

\[ \text{HP} = 20\% \text{ CP without any additives} \]

\[ \text{LPpb} = 16\% \text{ CP+ probiotic (\textit{Bioplus 2B: B. subtilis and B. licheniformis})} \]

Garcia et al. (2014)

Integrated approach – synergistic effect of low CP with probiotics and fibers
Reduction of dietary CP reduced urine N excretion and fermentable fiber shifted N excretion from urine to feces in 24 kg pigs

Diets:
High CP = 19% CP
High CP + Fiber = 18% CP + 15% soybean hulls
Low CP = 16% CP
Low CP + Fiber = 16% CP + 15% soybean hulls

Design: N balance
Initial BW = 24 kg

Zervas and Zijlstra (2002)

Integrated approach – synergistic effect of low CP with probiotics and fibers
Excess dietary of CP is the main cause for N pollution

- Partial replacing of protein sources with AA improves N utilization.
- Ammonia emission mainly originates from urinary N excretion.

Leek et al. (2005)

Application of low CP diet to mitigate environmental impact of pig production
# Effect of reducing CP on N-balance of 65-kg growing pigs

<table>
<thead>
<tr>
<th>Animals</th>
<th>Growing pigs in N-balance (initial BW 65 kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments</td>
<td>4 CP levels (18.9, 16.7, 14.6, 12.3%)</td>
</tr>
<tr>
<td>Diets</td>
<td>Corn, wheat, SBM, SPI-6 AA</td>
</tr>
<tr>
<td>Formulation</td>
<td>Same adequate SID AA and NE</td>
</tr>
<tr>
<td>Lys:CP, %</td>
<td>4.8, 5.4, 6.1, 7.2</td>
</tr>
</tbody>
</table>

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**Le Bellego et al. (2001)**

**Application of low CP diet to mitigate environmental impact of pig production**
Reduction of dietary CP (4%-unit) on performance and ammonia emission

Canh et al. (1998)

1%‐point CP reduction results about 12% reduction in NH₃ emission.

Application of low CP diet to mitigate environmental impact of pig production
**Effect of dietary CP level on water consumption and urine excretion**

<table>
<thead>
<tr>
<th>Animals</th>
<th>8 growing pigs (46 kg BW); N-balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments</td>
<td>2 CP levels (25 or 18.5%)</td>
</tr>
<tr>
<td>Diets</td>
<td>Barley-SBM-4 AA</td>
</tr>
<tr>
<td>Formulation</td>
<td>Same AA and ME</td>
</tr>
</tbody>
</table>

**Application of low CP diet to mitigate environmental impact of pig production**

<table>
<thead>
<tr>
<th>Dietary CP content, %</th>
<th>Water intake, g/d</th>
<th>Urine excretion, g/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.0</td>
<td>5427</td>
<td>-20%</td>
</tr>
<tr>
<td>18.5</td>
<td>4318</td>
<td>-59%</td>
</tr>
</tbody>
</table>

- Protein intake g/d: 479, 311
- Dry matter intake g/d: 1910, 1917

Pfeiffer & Henkel (1991)
Reducing dietary CP increases N retention and reduces N excretion (11 to 88 kg initial BW)

12 N-balance trial results (1998-2014); CP reduction: 2 to 8.5%-points

On average, 1%-point CP reduction results about 9% reduction in N output.

Application of low CP diet to mitigate environmental impact of pig production
### Scenario:

- **BW:** 25 to 115 kg
- **Produced:** 55 million pigs
- **Feeding:** 3 phases
- **Dietary CP:** 15.6, 14.5, 13.3%

### Table: Potential to decrease N excretion for pig production in Germany (25 to 115 kg BW; 2017)

<table>
<thead>
<tr>
<th>Diets:</th>
<th>Normal CP</th>
<th>Low CP</th>
<th>Low CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Added AA:</td>
<td>Lys, Thr, Met</td>
<td>Lys, Thr, Met, Trp</td>
<td>Lys, Thr, Met, Trp, Val</td>
</tr>
<tr>
<td>Average CP, %:</td>
<td>15.6</td>
<td>14.5</td>
<td>13.3</td>
</tr>
<tr>
<td>Total N excretion (thousand ton)²</td>
<td>149</td>
<td>125</td>
<td>99</td>
</tr>
<tr>
<td>Reduction in N excretion (thousand ton)</td>
<td>24</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Reduction in slurry (million ton)³</td>
<td>3.33</td>
<td>7.04</td>
<td></td>
</tr>
<tr>
<td>Reduction in land for manure (thousand ha)³</td>
<td>139</td>
<td>294</td>
<td></td>
</tr>
</tbody>
</table>

---

1. Assumed average FCR of 2.60 from 25-115 kg grow-out phase.
2. Assumed N retained of 53% for normal CP diet; 1%-point CP reduction = 9% N output reduction.
3. Based on 7.1 kg N/ton of pig slurry.
4. Based on 170 kg N/ha (fertilizer ordinance, 2017).

---

*Application of low CP diet to mitigate environmental impact of pig production*
### Scenario:
- **BW:** 25 to 115 kg
- **Total feed (grower-finisher):** 182 mil. MT (67% of total*)
- **Pigs:** 790 million
- **Feeding:** 3 phases
- **Dietary CP:** 15.6, 14.5, 13.3%

* 2017 ALLTECH GLOBAL FEED SURVEY

### Application of low CP diet to mitigate environmental impact of pig production (25 to 115 kg BW; 2017)

<table>
<thead>
<tr>
<th>Diets:</th>
<th>Normal CP</th>
<th>Low CP</th>
<th>Low CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Added AA:</td>
<td>Lys, Thr, Met</td>
<td>Lys, Thr, Met, Trp</td>
<td>Lys, Thr, Met, Trp, Val</td>
</tr>
<tr>
<td>Average CP, %:</td>
<td>15.6</td>
<td>14.5</td>
<td>13.3</td>
</tr>
<tr>
<td>Total N excretion (million ton)$^3$</td>
<td>2.14</td>
<td>1.80</td>
<td>1.42</td>
</tr>
<tr>
<td>Reduction in N excretion (million ton)</td>
<td>0.34</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td>Reduction in slurry (million ton)$^3$</td>
<td>48</td>
<td>101</td>
<td></td>
</tr>
<tr>
<td>Reduction in land for manure (million ha)$^3$</td>
<td>2.0</td>
<td>4.2</td>
<td></td>
</tr>
</tbody>
</table>

$^1$ Assumed average FCR of 2.60 from 25-115 kg grow-out phase.
$^2$ Assumed N retained of 53% for normal CP diet; 1%-point CP reduction = 9% N output reduction.
$^3$ Based on 7.1 kg N/ton of pig slurry.
$^3$ Based on 170 kg N/ha (fertilizer ordinance, 2017).
If 50% of SBM used comes from a LUC*-origin, Global Warming Potential is drastically improved by 2%-pt CP reduction (e.g. for FU: 1 ton LW)

**Scenario**

**BW:** 25 to 115 kg  
**For:** 1 MT live wt  
**CP:** 15 to 13.6%

<table>
<thead>
<tr>
<th>Vision High CP, SBM 50% LUC</th>
<th>Net Impact Feed</th>
<th>Net Impact Live Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choose another diet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>View Ingredients</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-346.10 kg CO₂e/mt</td>
<td></td>
</tr>
</tbody>
</table>

You get the following ecological differences:

- **CO₂**
  - Vision High CP: 366.69 kg CO₂e/mt
  - Vision Low CP: -1051.59 kg CO₂e/mt
- **SO₂**
  - Vision High CP: 1.77 kg SO₂e/mt
  - Vision Low CP: 1.73 kg SO₂e/mt
- **PO₄**
  - Vision High CP: 68.34 kg PO₄e/mt
  - Vision Low CP: 135.91 kg PO₄e/mt
- **H₂O**
  - Vision High CP: -14.83 m³ H₂O/mt
  - Vision Low CP: 2.53 m³ H₂O/mt

* LUC = Land use change.

**Application of low CP diet to mitigate environmental impact of pig production**
Calculated ecological footprint for current pig production in Germany
(15% CP diet; 50% SBM LUC-origin)

<table>
<thead>
<tr>
<th>Pigs slaughtered per year</th>
<th>Grow out wt (kg)</th>
<th>GWP* CO₂e/kg LW</th>
<th>Million tons LW</th>
<th>GWP Million tons CO₂e</th>
<th>AP* (kg SO₂/kg LW)</th>
<th>AP thousand tons SO₂e</th>
<th>EP* (kg PO₄/kg LW)</th>
<th>EP thousand tons PO₄e</th>
</tr>
</thead>
<tbody>
<tr>
<td>55 million</td>
<td>120</td>
<td>3.1</td>
<td>6.6</td>
<td>23.1</td>
<td>0.035</td>
<td>231</td>
<td>0.02</td>
<td>132</td>
</tr>
</tbody>
</table>

* Values for GWP, AP and EP per kg live weight: average literature values
(GWP=Global warming potent.; AP=Acidification potent.; EP=Eutrophication potent.)

Application of low CP diet to mitigate environmental impact of pig production
Mitigation potential by formulating low CP pig diets for pigs produced in Germany (AMINOFootprint 2.1<sup>®</sup>)

<table>
<thead>
<tr>
<th>Diet scenario</th>
<th>Saving CO&lt;sub&gt;2&lt;/sub&gt;e</th>
<th>Acidification Potential (AP) saving</th>
<th>Eutrophication Potential (EP) saving</th>
<th>Water saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>15% CP / 13.5% CP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No LUC SBM&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.37 mil. ton (1.6%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50% LUC SBM&lt;sup&gt;1&lt;/sup&gt;</td>
<td>2.5 mil. ton (11%)</td>
<td>40.7 thousand ton (17.6%)</td>
<td>11.9 thousand ton (9.1%)</td>
<td>97.9 million m&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>100% LUC SBM&lt;sup&gt;1&lt;/sup&gt;</td>
<td>4.6 mil. ton (20%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100% LUC SBM&lt;sup&gt;2&lt;/sup&gt; / no LUC SBM&lt;sup&gt;3&lt;/sup&gt;</td>
<td>7.2 mil. ton (31%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup>Included in both diets; <sup>2</sup>Included in 15% CP diet; <sup>3</sup> in 13.5% CP diet.

Application of low CP diet to mitigate environmental impact of pig production
Take home messages

- CP level in pig diets can be reduced by at least **2 % points** without affecting performance and carcass quality when balanced for EAA (SID basis; ideal AA ratio) and NE.

- Formulation of low CP diets using supplemental AA allows that are **cost effective** and more **environmentally friendly**.

- Integrated approach of using low CP pig diets with probiotics and fiber sources **further improves gut health and nutrient efficiency** of pigs.

- On average, **1%-unit** dietary CP ↓ » ~ 9% ↓ N excretion
  
  » ~ 12% ↓ NH₃ emission

- Reducing the dietary CP by 2 %-points for producing **55 million pigs** (25-115 kg) in Germany has potential to reduce:
  
  - **50 thousand ton less N excretion** (7 million ton less slurry)
  - **2.5 million ton less CO₂e** global warming potential (11% reduction)
Thank you for your attention!